IAEA-TECDOC-964

One decade after Chernobyl: Summing up the consequences of the accident

Poster presentations — Volume 2

International Conference held in Vienna, 8–12 April 1996

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The originating Section of this publication in the IAEA was:

Radiation Safety Section
International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, Austria

ONE DECADE AFTER CHERNOBYL:
SUMMING UP THE CONSEQUENCES OF THE ACCIDENT
POSTER PRESENTATIONS — VOLUME 2
IAEA, VIENNA, 1997
IAEA-TECDOC-964
ISSN 1011-4289

Printed by the IAEA in Austria
September 1997

FOREWORD

The consequences attributed to the disastrous accident that occurred at the Chernobyl nuclear power plant on 26 April 1986 have been subjected to extensive scientific examination; however, they are still viewed with widely differing perspectives. It is fitting then that, ten years after the accident, the European Commission (EC), the International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) should jointly sponsor an international conference to review the consequences of the accident and to seek a common and conclusive understanding of their nature and magnitude. The International Conference on One Decade after Chernobyl: Summing up the Consequences of the Accident was held at the Austria Center, Vienna, on 8–12 April 1996.

Five other organizations of the United Nations system — the United Nations Department of Humanitarian Affairs (UNDHA), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and the Food and Agriculture Organization of the United Nations (FAO) — together with the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), co-operated in the organization of the Conference, demonstrating a community of interests internationally.

The Conference recapitulated the International Chernobyl Project of 1990 and took particular account of the findings of two related conferences. These were: the WHO International Conference on the Health Consequences of the Chernobyl and other Radiological Accidents, held in Geneva, 20–23 November 1995, and the First International Conference of the European Commission, Belarus, the Russian Federation and Ukraine on the Consequences of the Chernobyl Accident, held in Minsk, 18–22 March 1996. The Conference also considered the results of an International Forum on One Decade after Chernobyl: Nuclear Safety Aspects, jointly sponsored by the IAEA and the UNDHA. The Forum was held at the IAEA Headquarters in Vienna on 1–3 April 1996 and addressed a number of nuclear safety issues, including the measures taken since the accident to improve the safety of Chernobyl type RBMK reactors and the safety of the containment structure (the so-called sarcophagus) built around the destroyed reactor and that of the site itself.

To facilitate the discussions of the Conference, background papers were prepared for the Technical Symposium by teams of scientists from around the world, who collaborated over a period of months to ascertain, consolidate and present the current state of knowledge in six key areas: clinically observed effects; thyroid effects; long term health effects; other health related effects; consequences for the environment; and the consequences in perspective: prognosis for the future. A background paper on the social, economic, institutional and political impact of the accident was prepared by Belarus, the Russian Federation and Ukraine. The conclusions of the Forum on Nuclear Safety Aspects served as a background paper on this topic. The Joint Secretariat expresses its thanks to all those distinguished scientists who co-operated in the rigorous preparation of these papers, and also to all the officers, the Advisory Committee and the Secretariat of the Conference for their participation, guidance and assistance.

The IAEA acted as host for both the International Forum and the final International Conference which recapitulated the consequences of the Chernobyl accident. Conclusions of the meetings mentioned and those of other international and national projects were reported at the Conference and integrated into a broad international consensus. Two major objectives of the Conference were: to agree on proven scientific facts and to clarify interpretations and prognoses in order to dispel confusion.

The Conference, which was presided over by Germany's Federal Minister for the Environment, Nature Conservation and Nuclear Safety, Ms. A. Merkel, attracted high level political participation, including that of the President of Belarus, the Prime Minister of Ukraine and Ministers from Russia and France. More than 800 experts, mainly in the fields of radiation protection and nuclear safety and including medical, environmental and engineering specialists, from 71 countries, participated. The Conference was also attended by 208 journalists from 31 countries — an indication of the continuing interest and concern of the international community.

An earlier publication in the IAEA Proceedings Series, issued in September 1996, contained a summary of the Conference results and the texts of oral presentations and discussions at the Conference. This IAEA-TECDOC reproduces the material from the poster presentations. It is in two volumes: Volume 1 contains the material from Sessions 1-4 and Volume 2 the material from Sessions 5-8 and the List of Participants.

The posters submitted in advance for presentation at the Conference were in many cases not consistent with established international scientific understanding of the effects of radiation and radioactive contamination. Nevertheless, in accepting posters for presentation, the Advisory Committee and the Joint Secretariat recognized that the topics under discussion were controversial. To meet the objectives of the Conference, namely to agree on proven scientific facts and to clarify interpretations and prognoses, it was considered important also to accept for presentation and discussion, so as to permit clarification, posters that showed apparent misinterpretations. For this reason, the poster papers accepted and included in these proceedings are of variable quality.

The Conference did much to fulfil the hope that it would be possible for scientists from around the world to reach a broad consensus on the major consequences of the Chernobyl accident. The results of this Conference deserve the widest possible dissemination, with the aim of consolidating knowledge and understanding of the consequences of the accident and permitting the countries most affected by those consequences to develop well informed and balanced policies for their alleviation.

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CHERNOBYL HOT PARTICLES IN THE LUNGS OF PERSONNEL INVOLVED IN THE POST-ACCIDENT CLEAN-UP ACTIONS AND OF INHABITANTS OF THE CONTAMINATED UKRAINIAN AND BELARUS TERRITORIES

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1. INTRODUCTION

For the purposes of that work the term 'Hot Particles' ('HP') is understood with the particulate radioactive aerosol, that shows the picture of hot spots when is investigated autoradiographically. Under the conditions of the accident the Chernobyl aerosol was formed because of the explosion of the Unit IV core, when the dispersed nuclear fuel and radioactive vapors and gases were released into the environment. There are two main types of 'Hot Particles' [1, 2]. The first one - the monoradionuclide beta-emitting particles occurred because of condensation the vapors of somewhat volatile fission products (Ru, Ba, I, Cs, etc.) on a dust. The second one - particles, consisting of radionuclides in various combinations. More often they consist of the grains of Unit IV spent nuclear fuel and contain the standard composition of fission products and alpha- and beta-emitting transuranics. Their radioactivity measured in activity of radionuclide tracer of the nuclear fuel. The sum of alpha-emitters $^{239}Pu + ^{240}Pu$ is usually used as that tracer [3 - 5]. The activity median aerodynamic diameter (AMAD) of the primary aerosol of nuclear fuel particles was about 12 μm [3 - 6].

The investigation of the body content by direct or indirect methods permits to determine the amount of the radioactivity inhaled and the relevant averaged over an organ committed doses. According to traditional dosimetry approach that is enough for rough prediction of committed detriment. For the real prognosis of the hazard due to aerosol inhalation in accordance with the alternative radiobiological model [7], it is necessary to know the microdistribution of deposited radioactive material as well as the relevant microdistribution of the deposited energy in target microstructures of the lungs. The only technique for investigating the microdistribution of a radioactivity is the histoautoradiographic examination of autopsy material.

There are two opposite points of view on the danger of 'Hot Particles' - from complete denying any importance of their impact on lungs up to obvious overestimate of their danger. Thus there are three problems in postaccident examination of internally exposed persons:

For the first - to determine the amount of radionuclides inhaled and to determine the average committed doses in lung structures. That problem for the witnesses of Chernobyl accident has been in general [4 - 6, 8].

The second - to determine the form of existence of radioactivity deposited in human lungs and to evaluate the relevant nonuniformity of the lung irradiation. That problem is discussed in this work.

The third - to predict a real risk, considering the dose rate and committed dose as well as the microdistribution of radioactive material in the lungs on the various times after the intake. That problem is the object for further investigators.

2. MATERIAL AND METHODS

The autopsy material was collected from three groups of persons that witnessed Chernobyl accident. The Group I has 27 persons from among ChNPP staff and firemen, died of acute radiation sickness in short time after the accident. The Group II has 12 persons, participating in 1986 - 1988 in remedial actions on the ChNPP site. Group III has 50 Ukrainian and 120 Belarus inhabitants, occupied the contaminated territories in 1986. Persons belonged to Groups II and III died in 1990 - 1992 due to different reasons.

The accident victims belonged to Group I died within 14 - 96 days following the acute inhalation of the Chernobyl aerosol. Investigation of their autopsy material began in 1986. Thus it was possible to find out only the reflections of the late phase of inhaled particles transport from deep regions of the human respiratory tract, presumably from alveolar ones. The 'Hot Particles' of two types described above might be found out in the material in 1986 - 1988.

The accident witnesses belonged to Groups II and III died in 1990 - 1992. Investigation of their autopsy material began in 1990. Thus it was possible to find out only the reflections of a very slow particle clearance from the alveolar region. The 'Hot Particles' only of nuclear fuel type described above might be found out in that material after 1990.

To standardize the collection of the autopsy material the special procedure was developed. According to it a lung complex was extracted completely, saving superior and inferior tracheobronchial lymph nodes. Then it was fixed in neutral 10% Formalin solution and sealed in aluminum tanks of volume 40 L. Each autopsy material was accompanied by the unified form of the legend containing the passport data of the dead person, his place of residing, place and character of his work at the time of the accident, pathological anatomy diagnosis.

The preliminary investigation had shown, that expected number of 'HP' in lungs of the main part of the accident witnesses would be low, without any preliminary information of their primary localization. So it was resolved to execute total lung examination, providing the following stages.

Stage 1. All lobes of the lungs were cut on a vertical axis on plates 10 mm thick. Each lung plate was marked and hermetically packed in 0.05 mm thick polyethylene package. The given procedure, preventing the withering of the pulmonary tissue, permits durably to save a material suitable for histological research.

Stage 2. To select the lung plates, containing radioactivity, they were placed between two sheets of the RM-1 X-ray photograph film (Russia) for autoradiographic examination. A special technique provided their dense and uniform contact avoiding an excessive pressure. Each plate was exposed for 30 days. The received autoradiographs permitted to define the microdistribution of a radioactivity: diffuse, local, or diffuse with local hot spots corresponding to localization of 'Hot Particles'.

Stage 3. The samples of volume about 2.0 cm^3, containing a hot spots, were cut from selected plates and processed histologically with standard paraffin-celluloid techniques. From each sample were produced about thousand sections 4 - 5 μm thick. Then all histological sections were fixed on glass microscopic slides. The sections, contained 'Hot Particles' were selected by X-ray autoradiographic technique, using the RM-1 X-ray photograph film. The duration of exposition was 30 days.

Stage 4. The selected histological sections were deparaffinizated and examined with histoautoradiography, using the A-2 nuclear photograph emulsion (Russia). Each section was exposed for 15 days. Histoautoradiographs, containing 'HP' were stained with hematoxylin and eosin. Two or three sections from each sample of pulmonary tissue taken out on the Stage 3 were selected for further histological investigation.

3. RESULTS AND DISCUSSION

3.1 'Hot Particles' in the lungs of the accident victims

The autopsy material from the persons belonged to Group I permits to investigate the special points of the 'HP' problem. They are: what particles can penetrate into the human lungs in the case of severe accident on the NPP, what is their quantity, size, radionuclide composition, behavior and other. The expected number of 'Hot Particles' in that material was high. That is why the autopsy material belonged to Group I of the accident victims was investigated by means of reduced procedure described above. Here Stages 1 - 2 were ignored. Samples of volume about 2.0 cm^3 from the central, root and peripheral departments of each lung lobe were investigated by means of Stages 3 - 4 of the general technique.

All 27 victims belonged to Group I were divided in 2 subgroups depending on a place of a presence at the moment of accident or the nearest hours after it. Subgroup I-A has 18 persons mainly belonged to ChNPP staff, involved in the service of the reactor or the turbines and worked in premises of the Unit IV. Subgroup I-B has 9 persons and includes firemen, guards and railway workers, worked outside the ChNPP buildings. Gamma-spectroscopy of samples showed, that the accident victims were exposed to aerosols of nuclear fuel particles and particles containing volatile beta-emitters: ^{106}Ru, ^{131}I, ^{140}Ba, ^{134}Cs and ^{137}Cs. The contribution of that beta-emitters to the total activity in the lungs was reliable higher for the persons from subgroup I-B [4]. That result is confirmed by our one. By means of histoautoradiography two types of particles were found out in autopsy material received from Group I. That were mixed alpha- and beta-emitting particles and 'pure' beta-emitting particles. The first ones made the majority and represented the nuclear fuel particles. Under the conditions of the accident the alpha-emitters were released only in form of grains of dispersed nuclear fuel. Repeated histoautoradiographic examination of the same material was made with periodicity in two years (in 1986, in 1988, in 1990 and in 1992). It showed, that in 1990 and 1992 the content of beta-emitting 'Hot Particles' on the slides was appreciably reduced, and 'HP' in a total were submitted mainly by alpha-emitting type. Thus yet it was possible to meet some 'pure' beta-emitting particles, consisted likely of ^{106}Ru.

More often the 'Hot Particles' were found in samples from the lower lung lobes, mainly from their central and root departments. All particles were located into macrophages that filled up some alveolar sacs and bronchioles. The contaminated macrophages were found out on a surface of alveolar walls and in alveolar interstitium too. That pictures reflect a radioactivity transport by macrophages through the lung tissues. They show, that on the early period after the intake the inhaled particles are in a motion and can irradiate a big volume of lung parenchyma.

Maximum number of 'HP' was found in the lungs of persons from subgroup I-A. The strict dependence between their number and spent time in the zone of the accident was not found out here. Nevertheless, some weak dependence of number of inhaled particles on a working place at the moment of the accident was observed. Apparently, that is connected to a sequence of aerosol propagation through working premises. All premises of the Unit IV were connected with an influent ventilation being in operation for some time after the explosion. So, two victims in the same time after the explosion were on the same distance from the damaged reactor, but in different premises. The first was in the premise for the electricians. The second was in the premise for the reactor operators. In one case it was found out more than 20 'Hot Particles' in histological section of the lung on an area of about 2 cm^2. In other case it was found out only one 'HP' in one of hundred of similar sections.

The number of alpha-emitting nuclear fuel particles in the lungs of the victims, included in subgroup I-B, was repeatedly below. Frequently they were not found out, may be due to reducing the techniques. The probability of their presence in the microskopic sections was less than 1/1,000. Here the strict dependence between number of particles inhaled and time spent in the zone of the accident was not found out too. It is necessary to add, that 3 persons from that subgroup used the 'Lepestok' respirator (Russia) for protecting the respiratory tract and that protective measure was effective.

It should be stipulated, that the absence of dependencies, mentioned above, took place for the people, witnessed only the first hours after the accident. In the subsequent temporary periods the distribution of aerosol in ChNPP premises and on ChNPP site acquired more uniform character. Thus the risk of an inhalation of 'Hot Particles' has appeared real for greater number of the accident witnesses from ChNPP staff and inhabitants of surrounding territories.

Even in cases with maximum lung contamination, 'Hot Particles' number per one macrophage, as appear, does not exceed unit. Therefore the level of activity in macrophage more than likely corresponds to activity of one particle. A linear diameter of particles, contained in cytoplasm of 10 macrophages from 10 casual pulmonary tissue fields were measured. It was shown, that their geometric dimensions are in the range from 0.2 to 1.0 μm. The total alpha-radioactivity of 'HP' found out in autopsy material from Group I, measured with the help of solid trek detectors in 1992, was in the range from $5\text{x}10^{-6}$ to $8\text{x}10^{-5}$ Bq [9]. In 1992 the specific total alpha-activity of the Unit IV spent nuclear fuel was about 20 MBq per gram of $^{238}UO_2$ with the specific activity of ^{239}Pu + ^{240}Pu of 15 MBq per gram [3]. The density of spent nuclear fuel is about 10 g/cm^3. Thus the linear diameters of the nuclear fuel particles, recognized by means of trek detector technique, were in the range from 0.4 to 1.0 μm. Our results of microscopic evaluations are in a good agreement with that estimates.

An aerodynamic diameter d_{ae} of aerosol particles with a linear diameter d_l and density ρ may be given by approximate equation: $d_{ae} = d_l\sqrt{\rho/\rho_1}$, where ρ_1 is the unit density. So aerodynamic diameters of deposited particles were in the range from 0.6 to 3.2 μm and were more less then AMAD of inhaled aerosol. Observed distinction reflects differences between dimensions of inhaled particles (primary aerosol) and particles penetrated into the alveolar region and deposited here. That effect is due to a filter capability of human respiratory tract.

The persons from Group I, who died of acute radiation sickness, were externally exposed in a dose range from 3.7 to 13.7 Gy [10]. The estimated equivalent dose in the lungs realized to the time of death was in a range from 0.3 to 120 mSv [4]. It was mainly due to inhalation of the aerosol of nuclear fuel particles. The realized doses represented not more than 6% of committed inhalation doses because of short time between inhalation and death for the members of Group I [8]. So high external doses and short time exclude the development of any biological effects in the respiratory tract of the victims, connected with internal exposure [10, 11].

3.2 'Hot Particles' in the lungs of the liquidators of the accident consequences and inhabitants of the contaminated territories.

The results of the investigation of the accident victims cannot be full transferred on survived accident witnesses, because acute radiation pathology of lungs had an effect on clearance of aerosol particles. For the first time it is true for self-cleaning function of lungs (e.g., infringement of drainage function of bronchi or mucociliary transport of particles).

The 'Hot Particles' were found out in only one case out of 12 included in Group II. That person was a driver of a sprinkler and participated in liquidation of the consequences of the accident in 1986. He died in 1990 of lung cancer. Alpha-emitting particles were found in two sections. They were located in cytoplasm of 3 macrophages. If in each macrophage the number of 'HP' does not exceed unit (see above), the whole number of them was not more than three. One macrophage, containing alpha-emitting particle, was placed on a surface of alveole, that shows an elimination of the nuclear fuel particle from the lungs on the fourth year after the accident. Besides main disease here the phenomena of chronic catarrhal and catarrhal purulent bronchitis were observed. Two another 'HP'-caring macrophages were found among elements of an inflammatory exudate.

In Group III the 'Hot Particles' were found out in lungs of three Belarus inhabitants. One of them was the participant of remedial actions at the ChNPP in 1986. These persons lived in Khoyniki and Vetka regions of Belarus. They died of casual reasons in 1990 - 1992. In lungs of one person was found interstitial fibrosis with perivascular and peribronchial fibrotic muffs formation (fibrosing alveolitis). In lungs of other two was found tuberculosis and catarrhal purulent deforming bronchitis. In all cases there were found out a few particles - not more than 2 or 3. They were located in fibrous tissue on a course of vessels and bronchi among nonradioactive dust particles.

All nuclear fuel hot particles found out in those cases, were an alpha-emitting and of the nuclear fuel type. The intake of aerosol of nuclear fuel particles for persons from Group II must not exceed that value for ChNPP staff, witnessed the accident and worked here in 1986 - 1987. Averaged over that cohort of accident witnesses it was equivalent to 0.2 kBq of $^{239}Pu + ^{240}Pu$ as a nuclear fuel tracer [4]. The intake of aerosol of nuclear fuel particles for persons from Group III was equivalent to 0.013 kBq of $^{239}Pu + ^{240}Pu$ [4].

Due to AMAD of primary nuclear fuel aerosol (12 μm as mentioned above), its fractional deposition in alveolar region did not exceed 1 - 5 % [12]. As the persons from Grout I died within short time after the accident, influence of a slow clearance of alveolar region on contamination of autopsy material was insignificant. The intake of aerosol of the nuclear fuel particles averaged over Group I was equivalent to 5.2 kBq of ^{239}Pu + ^{240}Pu as a nuclear fuel tracer [4]. So, the expected total number of the nuclear fuel particles in the alveolar region of their lungs at the time of death was about $4\text{x}10^7$ particles per kilogram. The expected frequency of the nuclear fuel particles in that case corresponds to about 7 particles per microscopic slide. The observed frequency of their presence in the microscopic sections was in the range from 1/1,000 to 20 particles per microscopic section.

Persons, belonged to Groups II and III, died approximately in 1700 days after the accident. Influence of a slow clearance of alveolar region on contamination of their lungs was significant. As expected [5], the total amount of particles in alveolar region of their lungs at the time of death did not exceed 0.2% of that inhaled due to accident. So, at the time of death the expected total number of the nuclear fuel particles in lungs' alveolar region of the persons from Group II did not exceed $5\text{x}10^4$ particles per kilogram. That corresponds to $1\text{x}10^{-2}$ alpha-emitting particles per microscopic slide. At the time of death the expected total number of the nuclear fuel particles in lungs' alveolar region of persons from Group III did not exceed $3\text{x}10^3$ particles per kilogram. That corresponds to $7\text{x}10^{-4}$ nuclear fuel particles per microscopic slide.

The observed frequencies of nuclear fuel particles appearance in autopsy material are in a good agreement with that prediction.

4. CONCLUSIONS

Thus, the results of conducted researches have shown, that the Chernobyl 'Hot Particles' were really inhaled by the witnesses of Chernobyl accident. Those particles were detained in their lungs for a long time. The most frequently they were found out in the lungs of the accident victims, essentially less often - in the lungs of the liquidators of the accident consequences. Risk of 'Hot Particle' inhalation was repeatedly below for the inhabitants of the contaminated territories. The dose in the lungs of people, made the second and the third group of the accident witnesses, should not be important for parameters of their health. That is confirmed by results of pathological anatomy research, which have not allowed to reveal any lung pathology authentically connected with 'Hot Particles' presence.

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A CONSIDERATION ON INTERNAL DOSE EVALUATION AND INTERVENTION BASED ON A SURFACE CONTAMINATION CONCEPT

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1. INTRODUCTION

Long-term radiation doses received by the inhabitants after the Chernobyl accident have been evaluated according to the surface contamination levels on the ground surface. The health effects have also been discussed by comparison between the surface-contaminated area and the uncontaminated control area. Selected protective measures were carried out in accordance with the contamination level of surface soil. These have been based on the 'surface contamination concept' which assumes that the radiation risk to inhabitants is proportional to the level of ground-surface contamination. The observations collected in regions around Chernobyl, however, show that the internal radiation doses to the inhabitants poorly correlate with the surface contamination level [1]. This fact poses a question on the suitability of dose evaluations and interventions based on this concept.

Such a non-linear relationship in the observations can be explained partly by the variation of transfer characteristics from soil to agricultural products [2,3]. Already in large variabilities of the soil-to-plant transfer factor (T_f) have been reported [4-8] as related to the difference in environmental conditions such as soil properties. The author and Uchida [2] have pointed out that an apparent concentration-dependency of transfer factors between soil and agricultural products [9, 10] is attributable to the spatial variation of soil sorption characteristics. Other numerical simulation results showed that radiocesium concentrations in crops would be unrelated to those in soils when the spatial-scale of contamination was large [3]. These findings suggest that previous procedures for dose evaluation, based on the surface contamination concept, need to be reconsidered for their suitabilities in case of a regional-scale contamination like the Chernobyl accident.

Environmental variability is an important but problematic subject when making decisions on intervention to agricultural activities. The maximum level of ground-surface contamination which can be considered safe should be derived differently for each site corresponding to its peculiar environmental features. However, it is difficult to determine site-specifically a derived intervention level for cultivation (DILC) for each field because such a variable criterion would give mental stress to the inhabitants who are eager to be equally treated. The DILC should be the same in despite of the environmental non-uniformity which is inevitable on a regional scale. It is desirable to resolve this controversy with the clear principle of doing more good than harm [11] by setting persuasive and effective framework for DILC determination, which cannot be found in previous studies dealing with post-accident intervention philosophies [12,13].

2. PROCEDURE OF DILC DETERMINATION

In general radiological assessments [14], radionuclide concentration in crop edible parts (C_{crop}) [Bq kg^{-1}] has been predicted by assuming a proportionality with the concentration in the soil as follows:

$$C_{crop} = T_f \cdot C_{soil} \quad (1)$$

where C_{soil} is the radionuclide concentration in the soil at harvest [Bq kg^{-1}]; and T_f, the soil-to-plant transfer factor [Bq kg-crop^{-1} per Bq kg-soil^{-1}]. Accordingly, the annual radionuclide intake by a consumer (I_y) [Bq y^{-1} man^{-1}] can be calculated by

$$I_y = I_c \cdot C_{crop} = I_c \cdot T_f \cdot C_{soil} \quad (2)$$

where I_c is the annual crop consumption by a consumer [kg y^{-1} man^{-1}].

The I_y calculated by eq.2 is unavoidably associated with uncertainties due to the potential variabilities of I_c and T_f. However, the DILC should be deterministic. For the purpose of protecting consumers' health, the DILC is desirably as low as possible. Conversely, many farmers would prefer a high DILC to avoid excessive socio-economic damages coming from loss of their jobs. Production of sufficient local food is a benefit also for consumers. A clear principle which must be persuasive for both consumers and farmers needs to be newly defined.

Therefore, the author proposes the following principle focusing on the responsibility of a farmer to the consumers' health:

'No farmer makes a consumer exceed the limit of intake'

This statement can be expressed in a different way as '*Cultivation is allowed for the farmer who does not make a consumer exceed the limit of intake*'. This principle is expected to balance the consumers' health risk and the farmers' socio-economic needs and be accepted by both parties. According to this principle, the DILC is determined flexibly corresponding to the number of farmers and the yield of agricultural products in the respective area.

In addition, the following three assumptions are given to determine the DILC:

1. The DILC is given as one deterministic value for the whole contaminated area.
2. Potential variabilities of environmental parameters are the same as the spatial variabilities of them collected in the area concerned.
3. Variation of internal doses among the inhabitants reflects the potential variation of the environmental parameters.

Here, as an unstable parameter, only a T_f is considered for its variability because the reported T_f values have a relatively large variation range [8]. Although variations of Y_c and I_c are possible, they are assumed here to be constant for calculational expedience.

In accordance with these assumptions, the number of consumers (N_{ex} [man]) who will exceed the annual limit of intake for a consumer (ALI_c [Bq y^{-1} man^{-1}]) per farmer is calculated as

$$N_{ex} = P_{ex} \cdot N_c \quad (3)$$

where P_{ex} is the potential probability of exceeding the ALI_c (I_y>ALI_c) for a consumer; N_c, the number of consumers per farmer [man]. The P_{ex} can change to a large extent depending on the variational characteristics of the T_fs.

Based on the principle already proposed, the N_{ex} should be less than one man. That is, cultivation is permitted when

$$N_{ex} < 1 \tag{4}$$

The DILC is defined as the value of C_{soil} at $N_{ex} = 1$.

The N_c in eq.3 is calculated by

$$N_c = \frac{Y_c}{I_c} \tag{5}$$

where Y_c is the annual crop yield per farmer [kg y^{-1}].

In the following section, sample procedures to determine the DILCs for ^{90}Sr and ^{137}Cs are shown for two crop species (cabbage and spinach) and two soil types (loam and sand). The annual limit of intakes for workers (ALIs) [15] have already been given for major radionuclides. The ALI_c was defined here as one-tenth the quantity of the ALI because the averaged dose limit for workers is ten times higher than that for the general public [11]. The ALI for ^{90}Sr is 6.0×10^5 [Bq y^{-1} man^{-1}] and that for ^{137}Cs is 1.0×10^6 [Bq y^{-1} man^{-1}] when the fractions of Sr and Cs reaching the body fluids following ingestion are assumed to be 0.3 and 1, respectively [15]. The variation characteristics of T_fs have been examined using the data collected by the International Union of Radioecologists [16]. The probability distributions of T_fs for ^{90}Sr and ^{137}Cs are shown in **Fig. 1**. Each of these distributions was approximated by a log-normal distribution, not by a normal one [8]. Their geometric means and standard deviations of the common logarithm are shown in Table I. The geometric means decreased in the order of sand, loam+sand, and loam for all the cases. For I_c [17] and Y_c [18], the averaged values in Japan were adopted (Table II); in the calculation, these values were converted to those on a dry-weight basis assuming that the water content was 0.9 [7]. It should be noted that all the values are specimens.

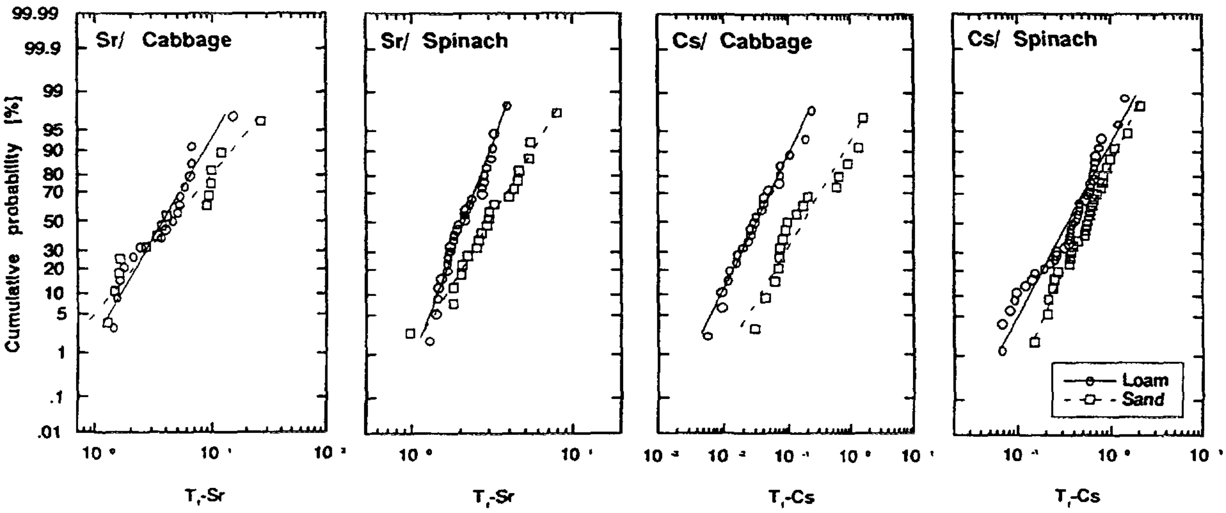

Fig. 1 Probability distributions of soil-to-plant transfer factor values on a dry-weight basis [8] collected by the International Union of Radioecologists [16].

Table I. Statistical values of soil-to-plant transfer factors on a dry weight basis [8] taken from the IUR Vth report [16].

crop	soil	Sr			Cs		
		n	geometric mean	std. dev. com. log.[a]	n	geometric mean	std. dev. com. log.[a]
cabbage	loam+sand	31	4.10	0.347	40	0.063	0.594
	loam	17	3.77	0.289	23	0.031	0.218
	sand	14	4.55	0.414	17	0.166	0.294
spinach	loam+sand	48	2.43	0.184	68	0.409	0.320
	loam	28	2.08	0.130	40	0.342	0.333
	sand	20	3.00	0.210	28	0.527	0.269

[a] The standard deviation of the common logarithm.

Table II. Parameter values relating to agricultural production and consumption.

crop	cultivated area $[m^2]$	annual crop intake per consumer [a] I_c [kg y^{-1} man^{-1}]	annual crop yield per farmer [b] Y_c [kg y^{-1}]	number of consumers per farmer N_c [man]
cabbage	4.04×10^8	7.48	1.16×10^5	1.55×10^4
spinach	2.73×10^8	5.22	4.26×10^4	8.16×10^3

[a] On a fresh weight basis [17].
[b] Averaged values in Japan [18] which was calculated by dividing the total crop yield by the total number of farmers.

3. RESULTS AND DISCUSSION

The relationships between C_{soil} and I_y are shown in **Fig. 2** for ^{90}Sr and **Fig. 3** for ^{137}Cs. These are shown for three T_f values: 5, 50, and 95 percentiles. Large variation ranges of I_y were obtained in all the cases, although each pattern differed. The degree of the variation corresponded to that of the T_fs. The N_{ex}s derived are plotted as a function of C_{soil} in **Fig. 4** for ^{90}Sr and **Fig. 5** for ^{137}Cs. Although the N_{ex}s increased with C_{soil}, the curves were not linear; they gradually approached the maximum value, i.e. the number of total consumers. The slopes tended to be more gentle in sand than in loam, which is due to the difference in the distributional patterns of the T_fs.

The values of DILC obtained as C_{soil} at N_{ex}=1 are shown in Table III. A large value was determined when the T_fs had a smaller variability (std. dev. com. log. in Table I). The order of magnitude of the DILC values did not necessarily correspond to that of the geometric means of the T_fs. For example, the DILCs of ^{137}Cs for cabbage and spinach were larger in sand than in loam+sand; oppsite results would be obtained if only the geometric means were considered. These findings suggested that information on the potential variability of each parameter is primarily important when determining the DILCs based on the proposed principle, i.e. farmers' responsibility for consumers. If a parameter had a large uncertainty due to lack of information, the DILC should be small enough to protect consumers

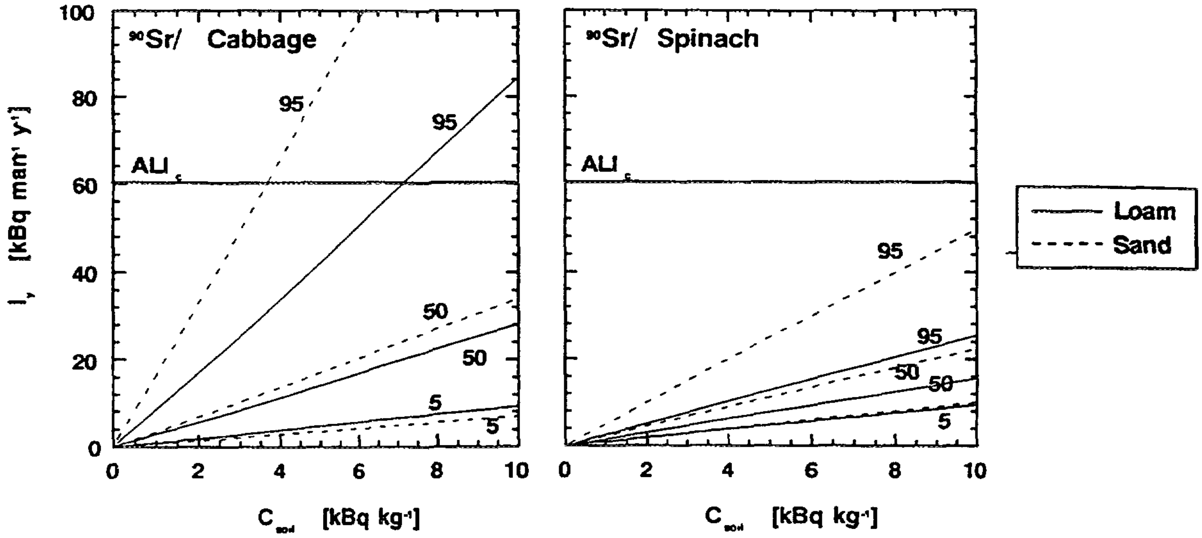

Fig.2. Plots of calculated annual intake of ^{90}Sr per consumer (I_y) versus the concentration in soil (C_{soil}).

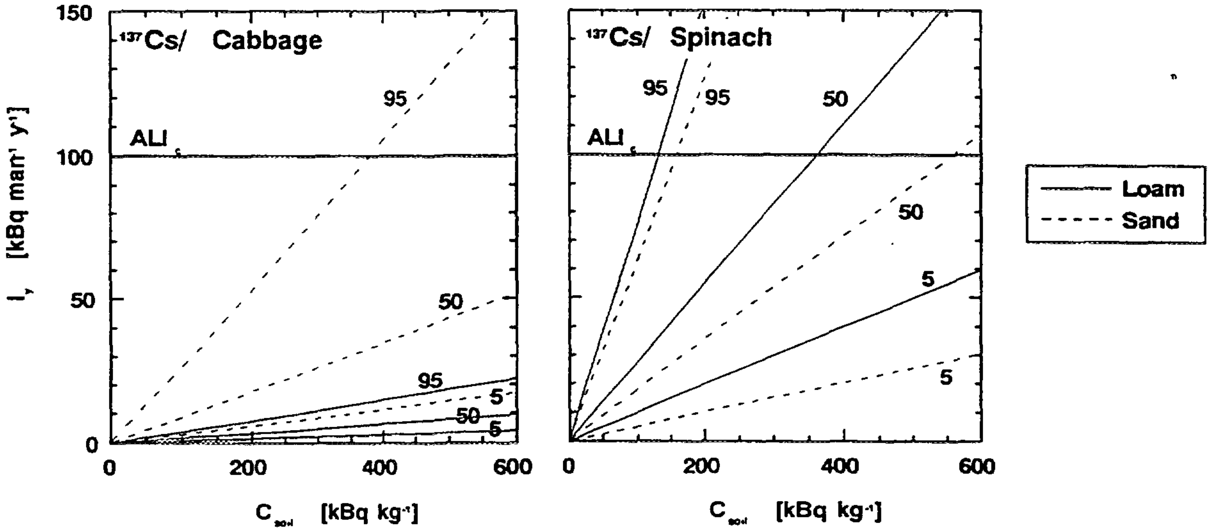

Fig.3. Plots of calculated annual intake of ^{137}Cs per consumer (I_y) versus the concentration in soil (C_{soil}).

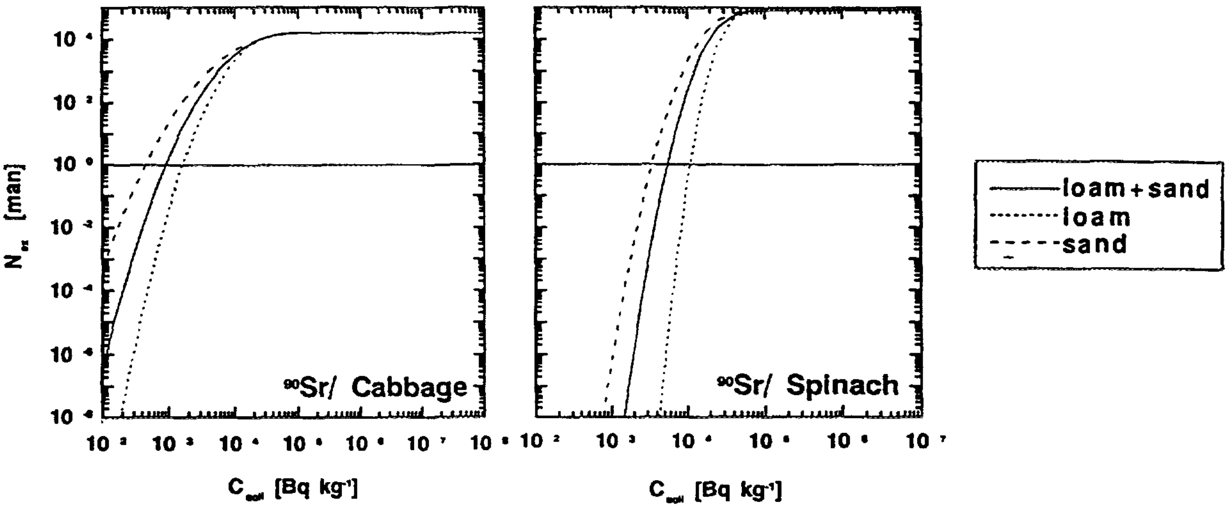

Fig. 4. Estimated numbers of consumers who would ingest ^{90}Sr above the ALI_c as a function of the ^{90}Sr concentration in soil.

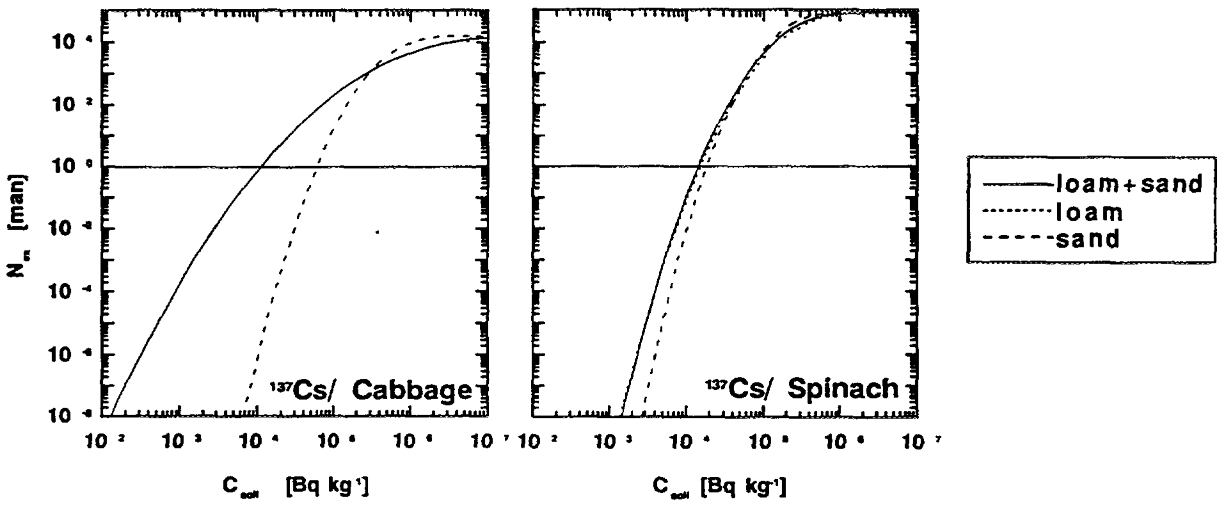

Fig. 5. Estimated numbers of consumers who would ingest ^{137}Cs above the ALI_c as a function of the ^{137}Cs concentration in soil.

Table III. Derived intervention levels for cultivation (DILCs) using the reference values shown in Tables I and II.

crop	soil type	DILC [Bq kg^{-1}]	
		^{90}Sr	^{137}Cs
cabbage	loam+sand	9.2×10^2	1.1×10^4
	loam	1.7×10^3	6.3×10^5
	sand	4.6×10^2	6.0×10^4
spinach	loam+sand	7.9×10^3	2.1×10^4
	loam	1.6×10^4	2.2×10^4
	sand	5.0×10^3	2.7×10^4

from the potential health risk. As a result, a large area would be restricted for cultivation and the farmers would suffer from excessive socio-economic disruption. Conversely, if sufficient observations were obtained, a suitable DILC should be set and a large number of farmers could avoid such damages.

After determining the DILCs, it is necessary to compare those values with the derived intervention levels of other protective measures such as evacuation and relocation. The DILC might not be necessary when other countermeasures are justified. IAEA [12] has reported that the derived relocation level (DILR) of ^{90}Sr and that of ^{137}Cs deposited on the ground are 3×10^8 [Bq m^{-2}] and 4×10^6 [Bq m^{-2}], respectively. Assuming both radionuclides are uniformly distributed in a surface soil having a density of 240 [kg m^{-2}] [19], the DILCs obtained here (Table III) were revised as 6.8×10^5 - 3.8×10^7 [Bq m^{-2}] for ^{90}Sr and 1.3×10^7 - 1.2×10^9 [Bq m^{-2}] for ^{137}Cs. By comparing these values with the DILCs obtained (Table III), the DILC for ^{90}Sr is necessary for protecting consumers because it is much smaller than the reference relocation level. Whereas the DILC for ^{137}Cs seems to be less important because farmers would be relocated at lower levels. It must be recognized, however, that the DILC for each radionuclide would change with crop species, soil properties, and eating habits. The DILC should be smaller when other contaminants exist in the soil. Dilution through market flow and removal by food preparation processes would reduce the radionuclide intake by consumers and allow a higher DILC to be set; these can be considered as other protective measures. Available countermeasures should be investigated regarding their possibilities with a thorough consideration of environmental, social and economic aspects.

It should be recognized that the DILCs shown in Table III are specimen values. A peculiar DILC needs to be determined for each situation using the information locally obtained. This study presented a framework for DILC determination which can be adopted flexibly to various contamination situations. Although more efforts to collect environmental parameters and to clarify their variabilities are needed for a reliable DILC determination, this framework is expected to protect people more suitably against the total damages resulting from a large-spatial scale contamination like the Chernobyl accident.

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XA9745803

THE LEVEL OF ^{137}Cs CONCENTRATION IN GREEK SOILS ONE DECADE AFTER THE CHERNOBYL ACCIDENT

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During nuclear accidents fission products are released in the atmosphere [1], [2]. These radioactive substances are transferred by the air in the form of radioactive cloud imposed on the ground or aspirated by the human and the animals and inevitably enter, in the biological circle.

The main characteristics, which determine how dangerous are the radio-nuclides, are their physical and biological half-life and the kind and the energy of their radiation emitted by them. From the long-living radionuclides, cesium (^{134}Cs and ^{137}Cs) and strontium (^{89}Sr and ^{90}Sr) isotopes burden the environment for greater time period. The absorbance of radioactive substances by the plants, by the man and animals can be direct and indirect. In the direct absorbance the plant but, also, man and animals are directly incorporating the radioactive substances. This way of incorporation plays an important role in the first days after the accident. The second way of incorporation - the indirect - presupposes the absorbance of radionuclides through the way ground - roots - plant - animal - man. The indirect way of contamination is the most important and influences the food for greater period of time.

One of the most serious consequences of the Chernobyl accident was the greatest radioactive contamination of the biosphere including the soil cover. It is well known that a soil analysis is a principal systematic method to estimate the radioactivity level in the particular area since deposition pattern is determined by measuring activity in grass and soil [3].

The aim of the present work is firstly to identify the level of the existing ^{137}Cs contamination over Greece ten years after the Chernobyl accident. Secondly, a comparison between the 1986 ^{137}Cs - distribution and the present measured one in more - less the same areas of Greece, has been attempted. The ^{40}K (0.0118% of natural K) concentration in soils as ratio $^{137}Cs/^{40}K$ has been, examined, even this ratio is not as constant in biological systems as the ratio Sr/Ca [4].

During the period of January 1993 - May 1995, 380 soil samples of surface soil (0-5 cm) were collected over Greece (Fig. 1). It was tried the soil samples to be taken from apparently undisturbed sites in open areas at the ground surface. Deeper soil samples (5-50 cm) were collected as well, but no didactable amount of ^{137}Cs has been recorded, as it was expected since the mobility for Cs is very low, 0.2 y^{-1} [5]. The sampling of surface soil, of about 500 cm^3 each, were taken from geographic divisions of Greece with emphasis to those where in 1986 serious depositions of ^{137}Cs (from 15 kBq/m^2 and more) were observed [6]. The ^{137}Cs concentration, near the soil surface is strongly time dependent , because of its variable deposition rates over many years and its gradual depletion by decay, erosion and leaching [7]. The uptake of ^{137}Cs from soil has been show to be inversely proportional to the K content of soils [4] that was also the case in the present work.

The ^{137}Cs average deposition in Greece was ranged in 1986 between, 0.01 to 137 kBq/m^2 [8]. Similar measurements of ^{137}Cs concentration in England for the period of 1990-1991, shows, a range of 0.7-0.8 kBq/m^2 [9], in Denmark the total

Figure 1: Total ^{137}Cs deposition on Greece (1995) following the Cernobyl accident

deposition of ^{137}Cs ranged from 0.66 to 3.6 kBq/m^2 [10] while the ^{137}Cs deposition in Italian soils had a mean value of 30 $\pm$17 kBq/m^2 immediately after the Chernobyl accident [5]. The present work estimates the ^{137}Cs accumulation in the Greek soils ten years after the Chernobyl accident, to be ranged between 0.4-14.4 kBq/m^2 (Fig. 2). The ^{40}K activity is between 5.1 and 16.5 kBq/m^2 (Fig. 3). ^{40}K and the radionuclides of the U and Th series contribute most of the naturally occurring radioactivity in soils. It is known that ^{40}K concentration in soils ranges between 0.51-15.54 kBq/m^2 [4].

All samples were kept in sealed containers for at least 15 days to allow equilibration between the isotopes ^{226}Ra and ^{222}Rn.

The collected soils samples were air-dried weighted and counted in Marinelli beakers with a gamma-spectroscopy system, consisting of a high purity coaxial Germanium detector p-type (CP2100, Tennelec). The sample chamber was a cylinder 12 cm in diameter and 25 cm in height and it was shielded by 5 cm of lead and 0.5 cm of copper in order to low the back ground. The full width at half maximum (FWHM) of the system was found to be 1.95 Kev at 1332 Kev of ^{60}Co. The linearity of the detector was checked with a ^{152}Eu source and a simple regression analysis gave a straight line with a correlation coefficient of 0.999. The radionuclides used were supplied by "The Nucleus", Oak Ridge, U.S.A. The counting time was 86,400 sec for all the soil samples in order the time to be sufficient to measure almost any level of radiocontamination (from 0.1 kBq/m²). The activity per unit mass (Bq/Kgr) of each sample was first evaluated. The activity per unit area (kBq/m²) was calculated afterwards by assuming the soil sample volume equal to the surface of a layer with depth 1 cm. The mean value and the standard deviation of the density of the 380 samples was 1.43 $\pm$0.23 Kgr/L. The concentration of ^{137}Cs and ^{40}K per prefecture all over Greece are given in Table I.

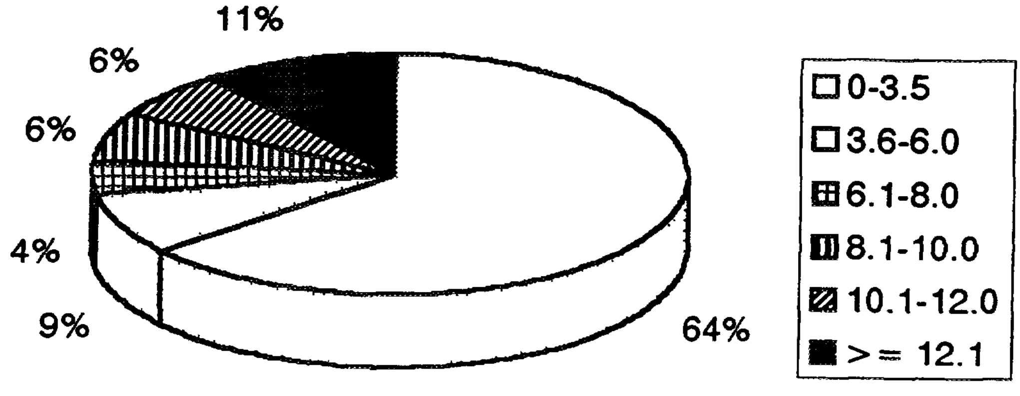

Figure 2: Percentage concentration of ^{137}Cs (kBq/m²)

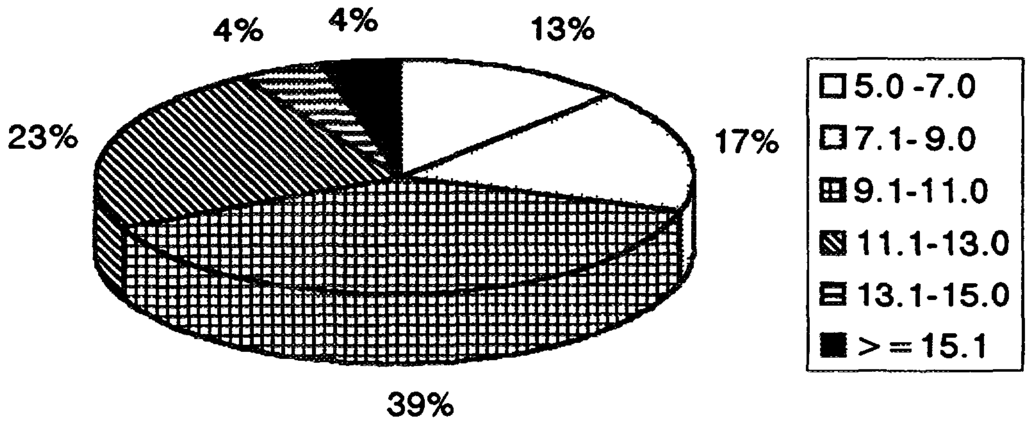

Figure 3: Percentage concentration of ^{40}K (kBq/m²)

Table I: Distribution of ^{137}Cs and ^{40}K per Prefecture in Greece

Ser. Num.	PREFECTURE	CAPITAL	Numb.of Samples	(kBq/m²)±SD	
				^{137}Cs	^{40}K
1	ACHAIA	Patra	8	1.8 ± 0.1	8.7 ± 0.2
2	ARGOLIDA	Nafplio	7	2.1 ± 0.1	9.9 ± 0.2
3	ARKADIA	Tripoli	7	3.1 ± 0.2	8.8 ± 0.3
4	ARTA	Arta	5	1.0 ± 0.1	9.4 ± 0.2
5	ATTIKI	Athens	10	4.0 ± 0.2	9.5 ± 0.3
6	CHALKIDIKI	Poligiros	11	3.0 ± 0.2	10.2 ± 0.2
7	CHIOS	Chios	4	0.4 ± 0.1	11.6 ± 0.3
8	CORFOU	Corfou	8	3.1 ± 0.2	10.5 ± 0.1
9	DODEKANISA	Rodos	5	0.4 ± 0.1	12.9 ± 0.2
10	DRAMA	Drama	8	4.8 ± 0.3	11.6 ± 0.1
11	ETOLOAKARNANIA	Mesologi	5	0.8 ± 0.1	12.9 ± 0.2
12	EVIA	Chalikida	6	0.7 ± 0.1	11.9 ± 0.4
13	EVRITANIA	Karpenisi	7	1.7 ± 0.1	14.3 ± 0.2
14	EVROS	Alexandroupoli	5	2.2 ± 0.1	15.8 ± 0.4
15	FLORINA	Florina	17	11.9 ± 0.3	8.2 ± 0.6
16	FOKIDA	Amfissa	8	1.6 ± 0.1	11.3 ± 0.7
17	FTHIOTIDA	Lamia	3	7.6 ± 0.2	6.2 ± 0.4
18	GREVENA	Grevena	7	10.6 ± 0.4	9.4 ± 0.3
19	ILIA	Pirgos	4	1.3 ± 0.1	9.9 ± 0.3
20	IMATHIA	Veria	15	12.7 ± 0.2	5.4 ± 0.1
21	IOANNINA	Ioannina	14	3.1 ± 0.4	11.1 ± 0.4
22	KAFALONIA	Argostoli	5	1.9 ± 0.1	10.7 ± 0.2
23	KARDITSA	Karditsa	14	12.5 ± 0.4	6.7 ± 0.3
24	KASTORIA	Kastoria	8	12.6 ± 0.5	6.6 ± 0.1
25	KAVALA	Kavala	6	2.7 ± 0.1	11.8 ± 0.4
26	KIKLADES	Ermoupolis	5	3.0 ± 0.2	12.8 ± 0.2
27	KILKIS	Kilkis	5	3.7 ± 0.1	10.0 ± 0.3
28	KORINTHOS	Korinthos	4	1.1 ± 0.1	10.1 ± 0.5
29	KOZANI	Kozani	10	8.8 ± 0.3	11.7 ± 0.2
30	KRITI (ISLAND)	Iraklio (l. town)	12	2.9 ± 0.2	10.7 ± 0.3
31	LAKONIA	Sparti	5	2.0 ± 0.1	8.9 ± 0.4
32	LARISA	Larisa	12	9.4 ± 0.2	8.1 ± 0.2
33	LESVOS	Mitilini	3	1.0 ± 0.2	11.8 ± 0.3
34	LIMNOS (ISLAND)	Mirina	5	3.5 ± 0.1	9.6 ± 0.5
35	MAGNISIA	Volos	12	7.9 ± 0.3	6.7 ± 0.4
36	MESSINIA	Kalamata	5	2.2 ± 0.2	10.9 ± 0.5
37	PELLA	Edessa	5	10.0 ± 0.5	7.6 ± 0.2
38	PIERIA	Katerini	18	14.4 ± 0.3	5.1 ± 0.1
39	PREVEZA	Preveza	5	1.4 ± 0.1	9.3 ± 0.2
40	RODOPI	Komotini	8	0.8 ± 0.1	10.1 ± 0.9
41	SERRES	Serres	11	4.0 ± 0.1	14.5 ± 0.5
42, 43	SKOPELOS, ALONISOS (SPORADES)	Chora of Skiathos	8	3.0 ± 0.1	9.9 ± 0.3
44	THESPROTIA	Igoumenitsa	6	2.8 ± 0.1	10.9 ± 0.3
45	THESSALONIKI	Thessaloniki	20	11.3 ± 0.4	7.8 ± 0.4
46	TRIKALA	Trikala	14	12.3 ± 0.6	7.9 ± 0.5
47	VIOTIA	Livadia	5	1.8 ± 0.1	10.2 ± 0.3
48	XANTHI	Xanthi	5	1.0 ± 0.1	16.5 ± 0.6

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CONSEQUENCES OF THE CHERNOBYL ACCIDENT IN LITHUANIA

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1. INTRODUCTION

After the Chernobyl accident of 26 April, 1986, population dose assessment favours the view that the radiation risk of population effected by the early fallout would be different from that in regions contaminated later. Taking into account the short half-time of the most important radioactive iodine isotopes, thyroid disorders would be expected mainly to follow the early fallout distribution.

At the time of accident at Unite 4 of the Chernobyl NPP, surface winds were from the Southeast. The initial explosions and heat carried volatile radioactive materials to the 1,5 km height, from where they were transported over the Western part of Belarus, Southern and Western part of Lithuania toward Scandinavian countries [1]. Thus the volatile radioiodine and some other radionuclides were detected in Lithuania on the very first days after the accident. The main task of the work - to conduct short half-time radioiodine and long half-time radiocesium dose assessment of Lithuanian inhabitants as a result of the early Chernobyl accident fallout.

2. RADIOIODINE DOSE ESTIMATION

Iodine radionuclides may be transferred through various environmental media before being taken into the human body, e.g. air-grass-cattle-milk-man pathway [2].

The behaviour of iodine in the atmosphere is of prime consideration to the nuclear industry and is especially important in the case of nuclear accident [3]. The physicochemical compounds of airborne ^{131}I released during the Chernobyl accident, were investigated world-wide although separation of radioiodine into aerosol-associated, gaseous inorganic and organic as well as relative concentration of each form were reported only for a few locations [4]. It was more common to determine only aerosol-associated radioiodine [5] and the estimations for the remaining radioiodine depended on the interpretation of modellers.

After the Chernobyl accident the most unexpected outcome of the airborne radioiodine measurements was the detection of inorganic and organic gaseous ^{131}I in abundance. Knowledge of radioiodine compounds abundance, deduced from these measurements, supports the evidence for necessity of standardized methods for aerosol-associated, gaseous inorganic (mostly $^{131}IONO_2$, ^{131}IO, $H^{131}I$, $HO^{131}I$ and night-time $^{131}I_2$) and gaseous organic (mostly $CH_3{}^{131}I$) measurements in the case of NPP accident [6]. These measurements are essential in the field of countermeasures available in the early phase of the NPP accidents, thyroid dose assessment as well as in NPP accident scenarios modelling.

The measurements of airborne radioiodine were performed in Lithuania during the period from 30 April to 10 May 1986. A special sampler was used to separate airborne radioiodine into three species: aerosol-associated (by means of Petrianov filters), inorganic gaseous radioiodine (by means of 2 beds of activated coconut charcoal) and organic gaseous radioiodine (by means of 2 beds of activated charcoal impregnated with triethylenediamine). All the samples were measured for radioactivity using Ge-Li high resolution spectrometry. The results of measurements are tabulated in Table I.

TABLE I. RADIOIODINE ACTIVITY CONCENTRATION IN ATMOSPHERIC AIR IN VILNIUS AFTER THE CHERNOBYL ACCIDENT (Bq m^{-3}) IN 1986

	^{131}I			^{132}I		^{133}I	
Sampling	FPA-15 (aer.)	BAU-A (inorg.)	BAU-A + HTMA (org.)	FPA-15 (aer.)	BAU-A + HTMA (gas)	FPA-15 (aer.)	BAU-A + HTMA (gas)
04.30	13±1	12.5±2	30±4	18±5	10±3	0.8±0.2	2.4±0.6
05.01	2.0±0.2	1.0±0.2	2.5±0.4	1.3±0.4	0.5±0.2	-	-
05.05	0.37±0.04	0.14±0.03	0.53±0.10	-	-	-	-
05.06	0.31±0.04	0.12±0.03	0.55±0.11	-	-	-	-
05.07	0.29±0.04	0.04±0.01	0.25±0.06	-	-	-	-
05.08	10.0±0.1	5.9±0.8	15.2±0.2	-	-	-	-
05.10	0.42±0.06	0.08±0.02	0.70±0.04	-	-	-	-

Radioiodine activity in pasture grass (Fig. 1) varied over a broad range as well as in milk consumed by inhabitants of Lithuania (Fig. 2). Milk activity reached a peak on the 4th day after deposition and then decreased with an effective half-time ranging from 4,2±0,6 days in more contaminated area to 5,2±0,9 days in other areas of Lithuania (Fig. 3) The value of the grass-milk transition coefficient was as large as 0.18±0.06 m^2 L^{-1}.

Thyroid examination by special dosimetric teams for assessing individual absorbed doses was not available in Lithuania for reasons beyond the control of experimenters. Although, once the concentration of radioiodine in a given environment is known, the amount of inhaled and ingested radioiodine can be estimated based on a model of iodine metabolism in a human body Referring to these data thyroid doses were calculated using the modified ICRP three-compartment cyclic model of iodine kinetics in the human body. This ICRP model was modified to include the effect of stable iodine intakes on radioiodine intakes explicity [7]. The probabilistic dose assessment method was

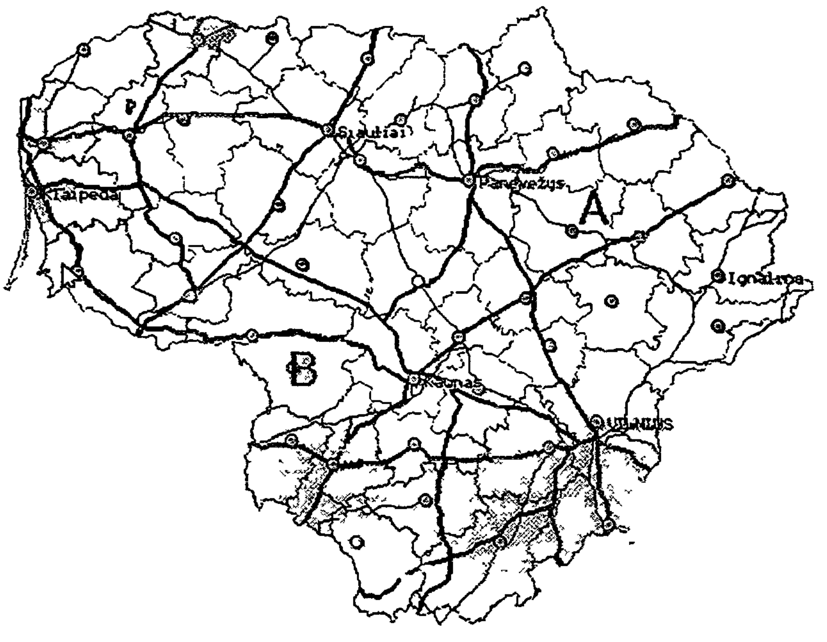

FIG 1. The peculiarities of pasture grass contamination by ^{131}I in Lithuania after the Chernobyl accident· A - the predominant radionuclide ^{131}I up to 2 kBq kg^{-1} fresh weight, B - radiocesium and some other isotopes, ^{131}I activity concentration up to 50 kBq kg^{-1} fresh weight

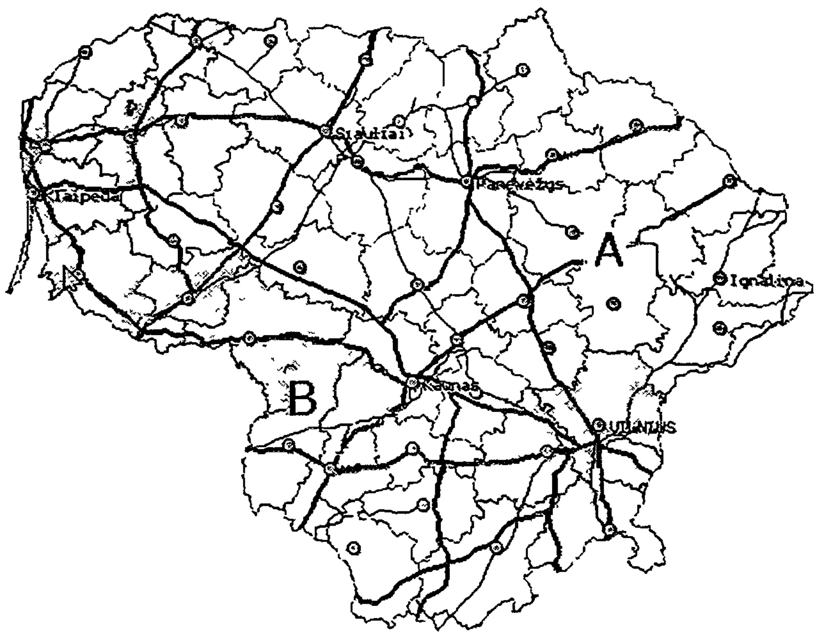

FIG 2. The peculiarities of milk contamination by ^{131}I in Lithuania after the Chernobyl accident A - less than tolerable ^{131}I intake level (370 Bq L^{-1} for infants), B - more than tolerable intake level (up to 10000 Bq L^{-1})

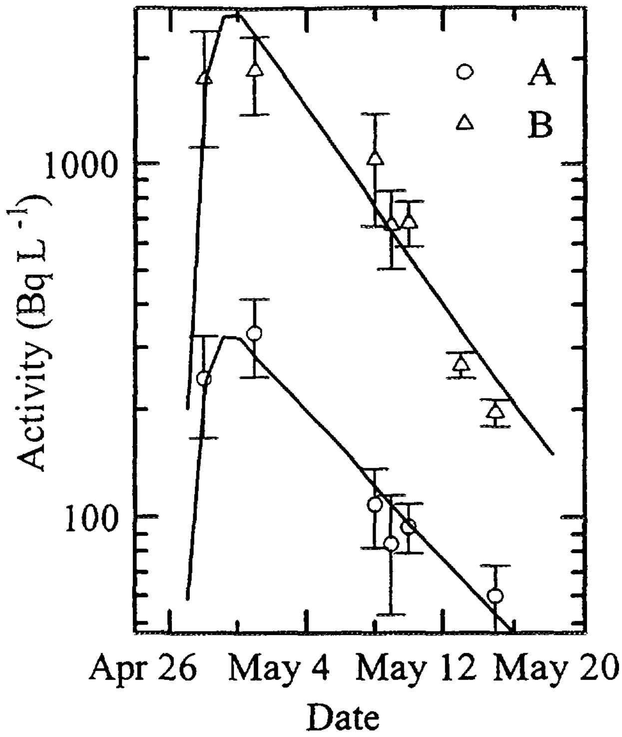

FIG. 3. Time dependent approximation of the observed ^{131}I activity concentration in milk in different areas of Lithuania (according to Fig. 2) after the Chernobyl accident

used in conjunction with more realistic estimates of doses. The consideration of regional iodine deficiency resulted in twofold increase of equivalent thyroid doses (Table II). It should be noted that the contribution of ^{132}I and ^{133}I inhaled on the very first days to the thyroid equivalent dose was insignificant - no greater than 0,12 mSv for adults and 0,34 mSv - for infants.

TABLE II. INFANT AND ADULT EQUIVALENT DOSES TO THYROID IN DIFFERENT AREAS OF LITHUANIA (ACCORDING TO FIG. 2) AFTER THE CHERNOBYL ACCIDENT

Age	Area	Equivalent doses to thyroid (mSv)						
		Without regard for iodine deficiency (determ.)	With regard to iodine deficiency					
			Determ.	Mean	s.d.	Median	Mode	95th per-cent.
Infant	A	10 ± 2	21	22	10	20	16	39
	B	73 ± 10	158	164	70	150	127	280
Adult	A	1.2 ± 0.2	2.7	2.8	1.0	2.6	2.3	4
	B	9.1 ± 0.9	20	21	7.5	20	17.7	28

Until recent time the epidemiology of thyroid diseases was not investigated in Lithuania. Apart from the consequences of the Chernobyl accident, the great source of potential radiation risk in Lithuania is the Ignalina NPP. Two of its functioning reactors are of the same type as in the Chernobyl NPP. This plant is listed among the most dangerous in Europe. That is why physicians and scientists of various fields units in solving the problem of thyroid diseases epidemiology in Lithuania. The joint project was initiated in 1992. This union was actively supported by Open Lithuanian Foundation and Lithuanian Health Ministry.

In addition the evaluation of influence of the Ignalina NPP on the number of thyroid disorders is under investigations. Interest in radiation risk around the Ignalina NPP has coincided with the building and licensing of this facility and undergoes a rise by virtue of the fact that during the period from 1984 to 1995 more than 300 GBq ^{131}I were released to the atmosphere [8]. That is why the environmental iodine monitoring and epidemiological studies are under investigation in this region. The fact that epidemiological studies of population are so difficult to interpret has been unseating for many epidemiologist and health physicist [9-11].

3. RADIOCESIUM DOSE ESTIMATION

The evaluation of radiocesium and radiostrontium intake with food into the human body in Lithuania was started at the beginning of 1965 and is continued until the present time. There was no considerable increase of radiostrontium in foodchain in Lithuania after the Chernobyl accident. This work deals with food contamination, annual intake and dose equivalent from radiocesium after the Chernobyl accident.

Concerning the evaluation of radiocesium intake with food particular attention has been given to the data of the first 3-y study after the Chernobyl accident. Intake of radiocesium to the human body was evaluated on the basis of analysis of individual diets and foodstuffs. The main components of foodstuffs, namely milk, meat, bread and vegetables, were collected in some districts every month. Samples were mixed thoroughly, dried and ashed at a temperature 450 °C. The ash was homogenized, weighted and placed in a counting beaker. Radiocesium activity concentrations were determined by using high resolution Ge-Li spectrometry or otherwise by chemical separation. The average annual radiocesium content in the main components of foodstuffs is presented in Fig. 4. Taking into account the radiocesium content in foodstuffs and individual diets, annual whole-body dose equivalent for infant, children and adult population according [12] have been calculated. As illustrated in Fig. 5, infant, children and adult dose equivalent from ^{134}Cs and ^{137}Cs in the Northern part of Lithuania was little more as compared with background, and in the Western part - no more than 50% higher than that after the nuclear weapon tests.

4. CONCLUSIONS

In Lithuania early fallout of the Chernobyl accident determined equivalent thyroid doses as high as 160 mSv for infants and 20 mSv for adults in comparison with radiocesium doses of two

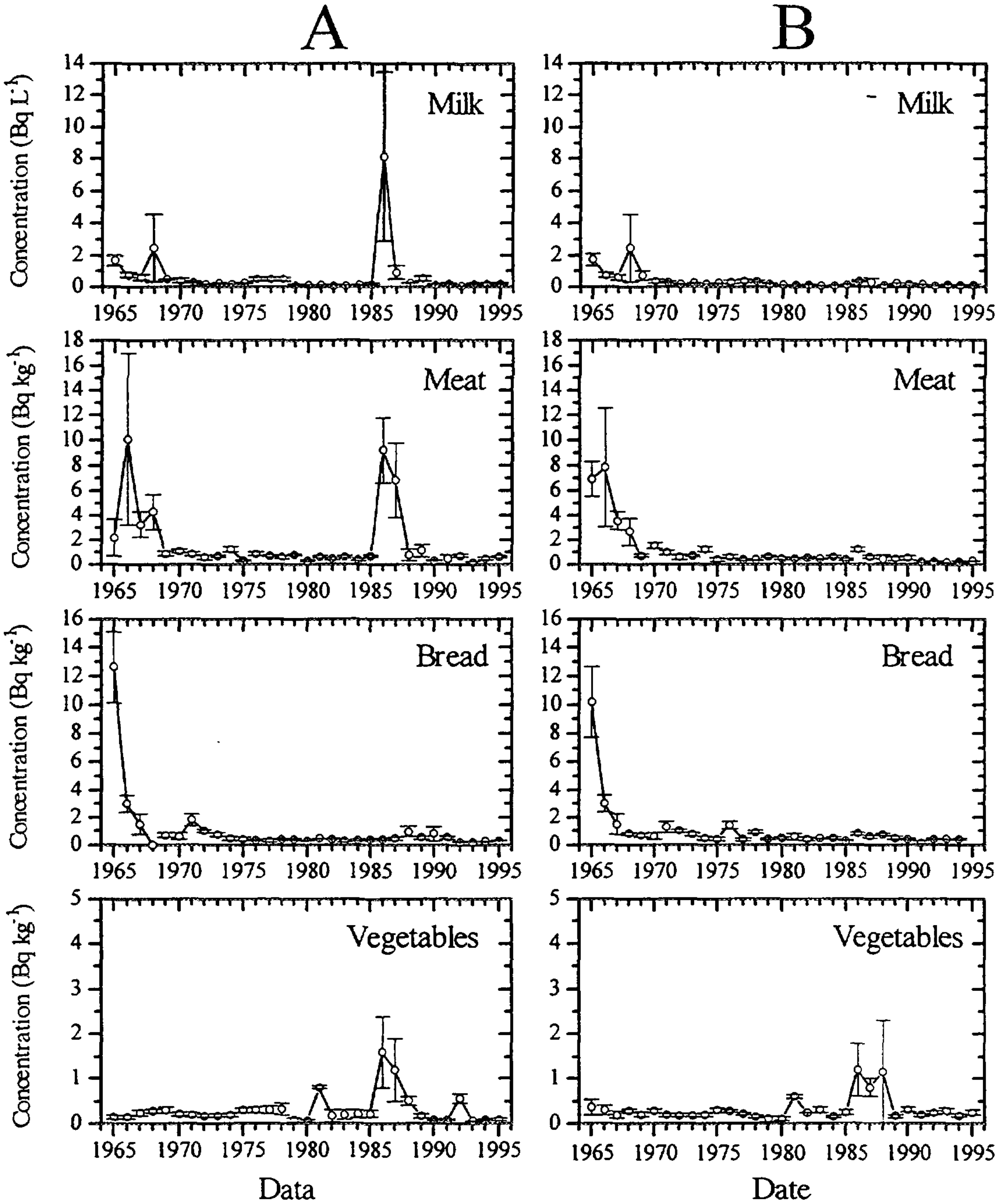

FIG. 4. Radiocesium activity concentration of the main components of foodstuffs in Lithuania (according to Fig. 2) during the period 1965 to 1995

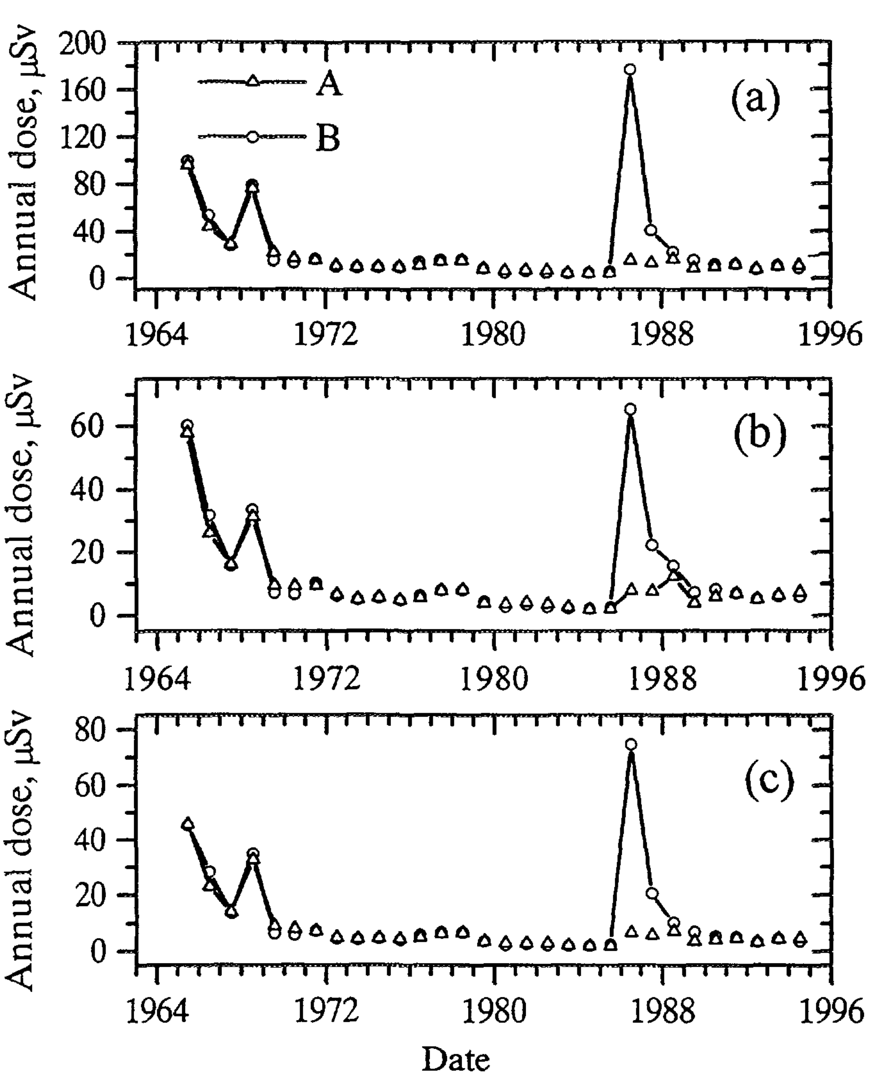

FIG. 5. Variations of whole-body radiocesium dose equivalent for infant (a), children (b) and adult (c) population in Lithuania (according to Fig. 2) during the period 1965 to 1995

orders of magnitude smaller. These data are inconsistent with that in regions contaminated latter [13].The present stage of investigation is focused on epidemiological and clinical studies of the thyroid disorders with consideration for the influence of the Ignalina NPP as 300 GBq of ^{131}I have been released in the NPP region since 1984 to 1993. The extrapolation of low doses health effects are still tentative, but there is growing promise, that information about the consequences of the Chernobyl accident will bring us closer to balanced view of radiation risk.

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XA9745805

CONTROL OF INTERNAL EXPOSURE DOSES OF BELARUS POPULATION

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Starting from May 1986 instrumental control of internal exposure is being carried out in Belarus using different equipment. In earlier, iodine period, the basic aim of the control was a mass screening of the population for defining of iodine content in thyroid. After the iodine period attention of the radiological control was focused on monitoring of caesium radionuclides content in human bodies of the inhabitants of radioactively contaminated territories. Goals of the control were changing, depending on the time that passed since the day of the accident.

Nowadays the National Commission of Belarus recognises entering of the Republic into rehabilitation period of the accident of the Chernobyl Nuclear Power Plant. Developed Conception of Protection Measures for the rehabilitation period for the population living at the territories affected by the radioactive contamination in the result of the Chernobyl catastrophe.

Control of internal exposure of the population was started to be carried out in May 1986 with mass measurements of radiological content in thyroid within the Republic population. In May-June 1986 brigades of dosimetrists measured radioiodine content in thyroid within more then 130,000 inhabitants. Estimates of thyroid exposure dozes were received on the basis of this data. They gave idea about doze distribution at the contaminated areas of Belarus. Since July 1986 when the first whole body counter (WBC) appeared in the Republic, the work over monitoring of incorporated gamma-irradiators in human body has begun.

During 1988-1994 the number of home produced WBC devices was replenished at the account of our WBC devices in three main modifications that differ only by the detector size or measurements geometry (Table 1).

Tasks of the control system were:

- evaluation of radioactive substances content in order to find out people with higher content of radionuclides in their bodies;

- evaluation of individual dozes of internal exposure based on the data of direct measurements for people, included into special groups for examination;

Table 1 Number of WBC devices and number of examined people in 1986-94

	1986	1987	1988	1989	1990	1991	1992	1993	1994
Number of WBC devices	3	3	11	17	24	35	55	82	83
Number of examined people (thousands)	36	60	59	99	95	174	109	131	89

- evaluation of factual doze loads of population, who live at the contaminated territories, to plan protective activities.

According to the official point of view, radiological control should have been applied to the whole population living at the contaminated territory (about 2 mln. people). therefore in order to organise a mass control over internal irradiation, the following conception, based on multi-stage introduction of control, was adopted:

- at the early, post-accidental stage, internal exposure control is firstly introduced for the population of the territories highly contaminated with radioactive caesium, because maximum entering of radiocaesium into a human body with foodstuff is expected just there. With the increase of root entrance of radionuclides into local products the accent in the organisation of control is shifted into territories where high values of radionuclides migration were registered in the "soil-plant" chain;

- taking into consideration relevant technical complexity and small number of WBC devices they are placed in regional centres on the base of regional hospitals and the population to be examined is transported there in accordance with the schedule developed in advance.

First years of radiological monitoring organisation showed drawbacks of this conception. They included not full embracing of the population by the control with the presence of necessary technical means, very low productivity of WBC devices, that was connected with transportation of the people to the places of their examination; decrease of people's interest towards WBC devices and imperfection of the WBC devices themselves. In addition to all these drawbacks, artificial facts (overestimation of indexes) when measuring of the inhabitants of certain territories, where medium levels of the contamination of agricultural output of local production were explained through rather high values of "minimum detected activity" of WBC devices in use and comparatively small content of incorporated activity in people.

After evaluation of the radiational situation in the Republic, the NCRP of Belarus stated entering into the rehabilitation phase of the Chernobyl accident and developed the conception.

As stated by the NCRP, radiation protection of the population, which is conditioned by the Chernobyl catastrophe, is conducted with the aim to eliminate possibilities of development of remote consequences for the present and future generations. It is achieved by making collective radiation dozes smaller, as well as by means of making individual dozes smaller within the population carrying out dosimetrical control as well as within a critical group.

All this made us recognise the conception of the organisation of mass control of population. In addition to the WBC devices that are currently in use in all areas, which have radioactively contaminated territories, it was suggested [1] to create groups of 2-4 mobile counters of human exposure with automatic WBC devices with high productivity and low "minimum detected activity", completed by groups of specialists, examining settlement according to the beforehand schedules and routes planned in advance. At the same time, acting fixed, non-movable WBC devices were shifted into the class of fixed, non-mobile devices and were modernised in order to decrease "minimum detected activity" and increase productivity.

At the result of realisation of these proposals there has been established the following hierarchical system in the Republic:

- the first level is made from fixed WBC devices with minimum detected activity on Cs-137 in the range 180-370 Bq on the human body;
- the second level is represented by mobile WBC laboratories with minimum detected activity about 200-700 Bq and productivity 120-180 people in one day;
- the third level includes simple monitors witnesses, radiometers of one-channel analizator for accidental and first preliminary estimate off human body contamination with radionuclides with minimum detected activity from 700 to thousands Bq, that nowadays are on conservation.

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2. Protection Measures for the rehabilitation period for the population living at the territories affected by the radioactive contamination in the result of the Chernobyl catastrophe

PREDICTIVE MODELS FOR PRACTICAL USE IN AQUATIC RADIOECOLOGY

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1. Introduction and aims

A given fallout of radiocesium will be distributed and taken up by biota differently in various types of lakes. Thus, lakes have different "sensitivities" to radiocesium. Important environmental factors regulating the biouptake are the water retention time and the K-concentration. Several practically useful and ecologically relevant methods exist to remediate lakes, e.g., liming, potash treatment and fertilization of low-productive lakes. The basic aim of this paper (which is a brief version of paper I) is to use the VAMP model, first to illustrate the fact that different lakes have different "sensitivities", and then to simulate the effects of alternative remedial methods.

The basic components of the VAMP model are outlined in Fig. 1. The model has been validated against an extensive set of data from seven European lakes (Table 1). It has been shown that the VAMP model yields just as good predictions as parallel sets of empirical data, and this is as good as any model can do (II). The main objective of the model is to predict radiocesium in predatory fish (used for human consumption) and in lake water (used for irrigation, drinking water, etc.). The conceptual approach linking model, remedy and costs is illustrated in Fig. 2.

2. Differences in lake sensitivity to radiocesium

The aim of this section is to analyse the concept of lake sensitivity. Fig. 3 first gives empirical data on Cs-concentrations in lake water after the Chernobyl accident (month 1 = January 1986). There is a very wide spread in concentrations of about 3-4 orders of magnitude. This is understandable, since fallout also varies by about 3-4 orders of magnitude (from 0.9 kBq/m^2 to about 100 for these 6 lakes, Iso Valkjärvi, Hillesjön, Devoke Water, Bracciano, IJsselmeer and Esthwaite Water, see Table 1). So, an interesting question is: What is the variation if the differences in fallout among the lakes are taken into account? In fig. 3B, the concentrations are normalized for fallout. The range is significantly reduced, but the variation still covers more than 2 orders of magnitude. This means that there are many other factors regulating the concentrations of Cs-137 in lake water beside fallout. One fundamental objective of the VAMP project is to address this question and develop and test models accounting for the most important processes regulating such variations.

Fig. 3C gives curves of Cs-concentrations in water predicted by the VAMP model, divided by the fallout for each lake. Note the marked seasonal variabilities in many small lakes (Esthwaite Water, Heimdalsvatn and Devoke Water) and the low seasonal variations in the deep Bracciano and large IJsselmeer. However, even after this normalisation, the differences between the lakes remain considerable (more than 1 order of magnitude).

The most important sensitivity factor for the other target variable, Cs-concentrations in predatory fish, are ions similar to Cs, like K, Ca, Na and Mg (II). The more of these ions, the lower the uptake of Cs-137, a case of "chemical dilution". Note also that for a single pulse, like after the Chernobyl accident, the

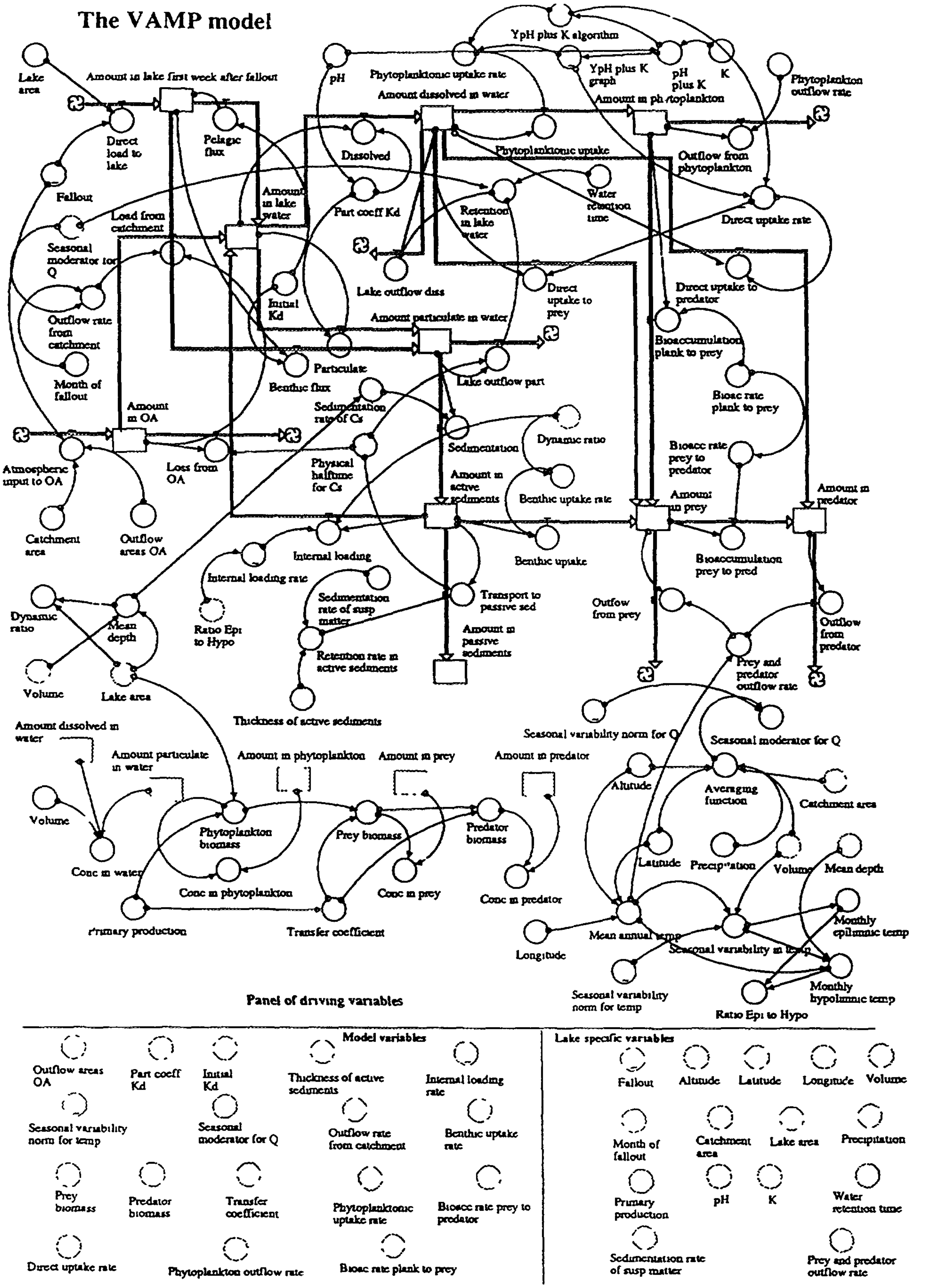


Fig 1 The VAMP-model for radiocesium in lakes Sub-models for biomasses and the seasonal moderators for water discharge (Q), and temperature, and the panel of driving variable are also shown. This panel is divided into two parts. "model variables" and "lake-specific variables". The lake-specific or environmental variables change for every lake, but ideally the model variables do not change, unless there are strong reasons to do so. This conservative rigour concerning *ad hoc* adjustments minimizes the "art" and maximizes the science in building predictive models

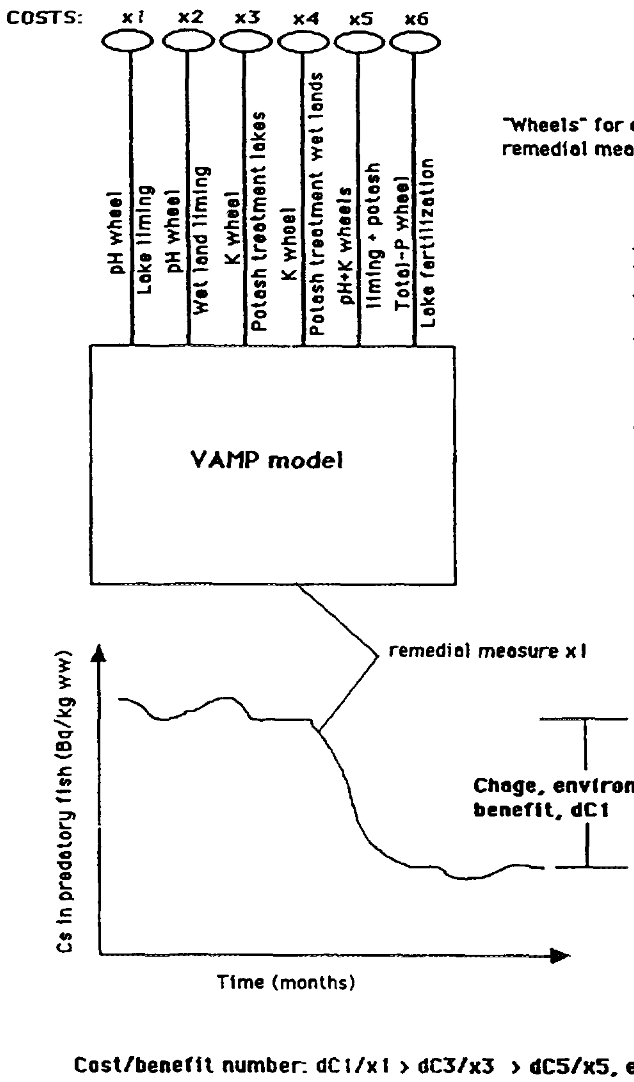
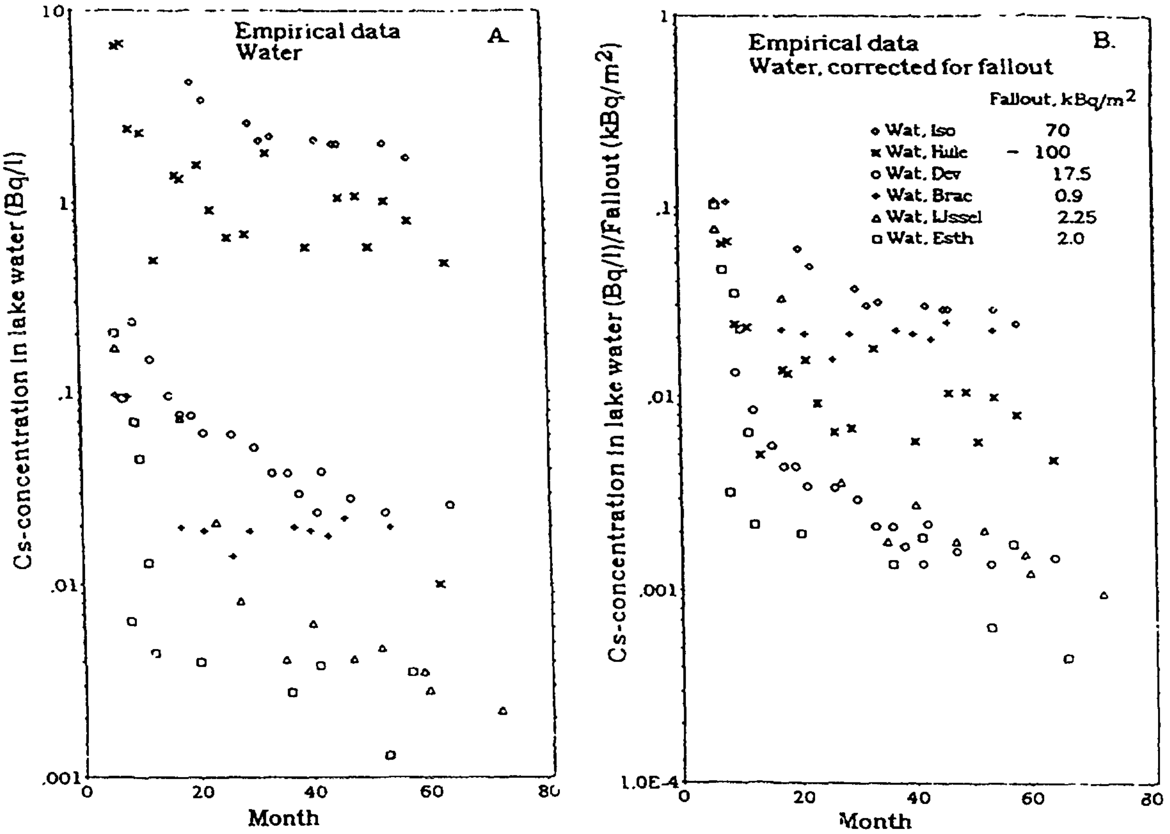


Fig. 2. Illustration of how to use a model (in this case the VAMP model) as a practically useful tool to test various remedial strategies and establish relevant environmental cost/benefit numbers related to the cost for the remedial measures (x1, x2, etc.) and the environmental benefit, as determined by the improvement in target variables (dC1, dC2, etc.).

Table 1. Data for the seven "VAMP-lakes". All lakes are oligohumic except Iso Valkjärvi and Hillesjön which are mesohumic. IJsselmeer, Hillesjön and Esthwaite Water are eutrophic and the remainder are oligotrophic. Prec. = precipitation; T = theoretical water retention time; K = potassium concentration in lake water; Prim. prod. = primary production; Susp. load = suspended load; Sed. rate = sedimentation rate of suspended matter; Cs-dep. = deposition of Cs-137. Max. conc. = measured maxiumum concentrations.

Lake	Altitude (m.a.s.l.)	Lat. °N	Lake area (km2)	Mean depth (m)	Catchment (km2)	Prec. (mm/year)	T (years)	pH
Iso Valkjärvi, Finland	126	61	0,042	3,1	0,168	600	3	5,1
Bracciano, Italy	164	42	57	89,5	91,2	900	137	8,5
Øvre Heimdalsvatn, Norway	1090	61	0,78	4,7	23,4	800	0,17	6,8
IJsselmeer, Holland	0	52	1147	4,3	114700	750	0,41	8,5
Hillesjön, Sweden	10	61	1,6	1,7	19,2	650	0,36	7,3
Devoke Water, U.K.	233	54	0,34	4,0	3,06	1840	0,24	6,5
Esthwaite Water, U.K.	66	54	1	6,4	14,0	1800	0,19	8,0

Lake	K (mg/l)	Prim. prod. (g C/m2*yr)	Susp. load (mg/l)	Sed. rate (g/m2*yr)	Cs-dep. (kBq/m2)	Prey fish	Max. conc. (Bq/kg ww)
Iso Valkjärvi	0,4	25	0,5	70	70	Whitefish & Perch	11650
Bracciano	40	0,8	0,5		0,9	Whitefish	14
Øvre Heimdalsvatn	0,4	27	0,3	60	130	Minnow&Trout	5250
IJsselmeer	7	350	40	500	2,2	Smelt, Roach & Perch	21
Hillesjön	3	100	5	0	100	Roach & Perch	4750
Devoke Water	0,55		0,5	300	17	Perch & Trout	1750
Esthwaite Water	0,9	350	1	700	2		



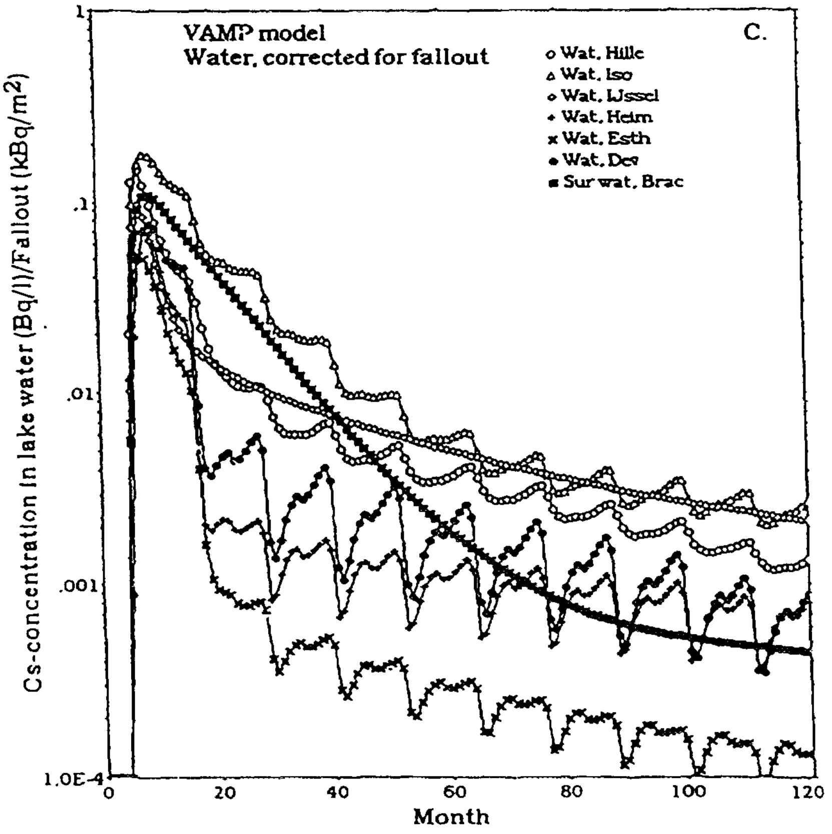


Fig. 3A. Empirical data of Cs-concentrations in lake water over time (month 1 = January 1986) for six of the VAMP lakes.
B. Corrected (or normalized for fallout) empirical data of Cs-concentrations in lake water over time (month 1 = January 1986) for six of the VAMP lakes.
C. Corrected (or normalized for fallout) predicted values of Cs-concentrations in lake water over time (month 1 = January 1986) for the VAMP lakes.

biouptake of Cs-137, and the Cs-concentration in fish, is lower in lakes with fast water turnover, a case of normal "water dilution". An increase in total-P, i.e., in lake production, causes a "biological dilution" of Cs-137 in lake biota (IV).

From this, certain important question may be asked:

• What can be done in practice (in a cost-efficient and realistic manner) to reduce (or speed up the recovery of) the Cs-concentrations in lake water and predatory fish?

• Is it possible to reduce the secondary load, i.e., the transport of radiocesium from land to water? Or the internal loading? Or the bioavailable portion of the lake load?

• Is it possible to test other remedies linked to the many factors regulating the differences among lakes? For example, lake liming to change pH, potash treatment to change the K-concentration, or fertilization (adding of phosphorus) to change lake bioproduction in low-productive lakes?

3. Remedial strategies

4.1. Model simulations of remedial measures

Different remedial measures have been tested to try to decrease the concentrations of radiocesium in fish (V). The VAMP-model will be used here to simulate consequences for Cs-concentrations in predatory fish from (1) liming, (2) potash treatment and (3) fertilization. No simulations are made for measures aiming at speeding up the recovery of Cs-concentrations in lake water, since this is regulated by factors which are very difficult to change (III).

3.1.1. Liming

Naturally low pH occurs in many oligotrophic lakes with catchments dominated by acidic rocks and mires. Natural, or pre-civilisation, values of lake pH vary from lake to lake. It is, clearly, not possible to measure today what the conditions used to be - but there are predictive methods (IV). In Sweden, a crude "rule-of-the-thumb" system is applied whereby lakes are generally limed to about 6.4-6.5.

The only VAMP lake with a very low pH is Iso Valkjärvi (pH = 5.1). Fig. 4A shows the predicted effects of liming on Cs-concentrations in pike when lake pH was increased in steps from 5.1 to 7.5: The higher the lake pH, the lower the Cs-concentrations in pike. In fig. 4B, the simulated liming was started at different months after contamination. The upper curve gives the default conditions (pH = 5.1), the next curve the results when a liming increased pH from 5.1 to 6.5 month 24 (i.e., January 1988). The following curves give the same results for different starting months (month 8, 10, 12, 15 and 18). The lowest curve gives the conditions when pH is set to 6.5 for the entire period. One can note that the sooner the liming starts, the better. Similar analyses were carried out for whitefish (I), which has a shorter ecological halflife than pike, and gives a more rapid response.

3.1.2. Potash treatment

One can increase pH without changing the concentration of potassium in the lake, such as by adding primary rock lime with no potassium, but it is not possible to increase the K-concentration without at the same time also increasing lake pH.

Fig. 5A shows the predicted effects of potash treatment on Cs-concentrations in pike when lake K-concentration was increased in steps from 0.4 to 38.4. The model predicts a significant influence on Cs-

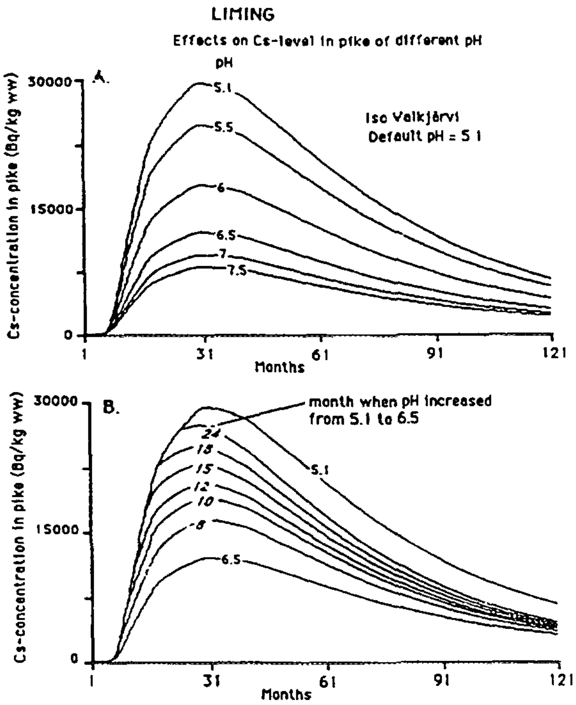


Fig. 4. Simulations illustrating the effect of liming on Cs-concentration in pike in Iso Valkjärvi using the VAMP model.

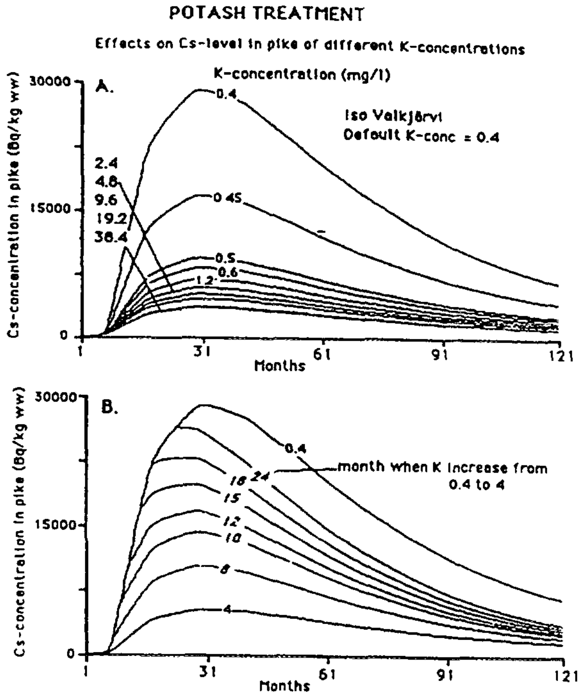


Fig. 5. Simulations illustrating the effect of potash treatment on Cs-concentration in pike in Iso Valkjärvi using the VAMP model.

concentrations in pike: The higher the K, the lower the Cs-concentrations in pike. In fig. 5B, treatment was started in different months: the upper curve gives the default conditions (K = 0.4), the next curve the results when a potash treatment increased K from 0.4 to 4 in month 24 (i.e., January 1988); the following curves give the results for different starting months (8, 10, 12, 15 and 18); and the lowest curve gives the conditions when K is set to 4 for the whole period. One can again note: The sooner the treatment starts, the better, and similar results can be applied to any species of fish.

3.1.3. Fertilization

Total phosphorus has long been recognised as the nutrient most likely to limit lake primary productivity (VI). Many practical management models for lake eutrophication have been presented (VII). Both experimental and comparative studies have been carried out of whole lake ecosystems to derive loading models for lake management (VII). A key element in this development was Vollenweider´s identification of the simple relationship between sedimentation of phosphorus and water turnover in lakes. Water turnover is therefore an important factor regulating the effect of a given load of phosphorus in lakes.

Fig. 6A shows the predicted effects on the Cs-concentrations in pike in Iso Valkjärvi of a hypothetical fertilization changing the primary production (in g C/m^2*year) from 25 in steps to 300: The higher the lake production, the larger the biomass and the lower the Cs-concentrations in pike. In fig. 6B, the effects of starting fertilization in different months are shown. The upper curve gives the default conditions (prim. prod. = 25), the next curve gives the results when a fertilization increased primary production from 25 to 100 in month 10; the following curves give the same results for different starting months (10, 20, 30,....

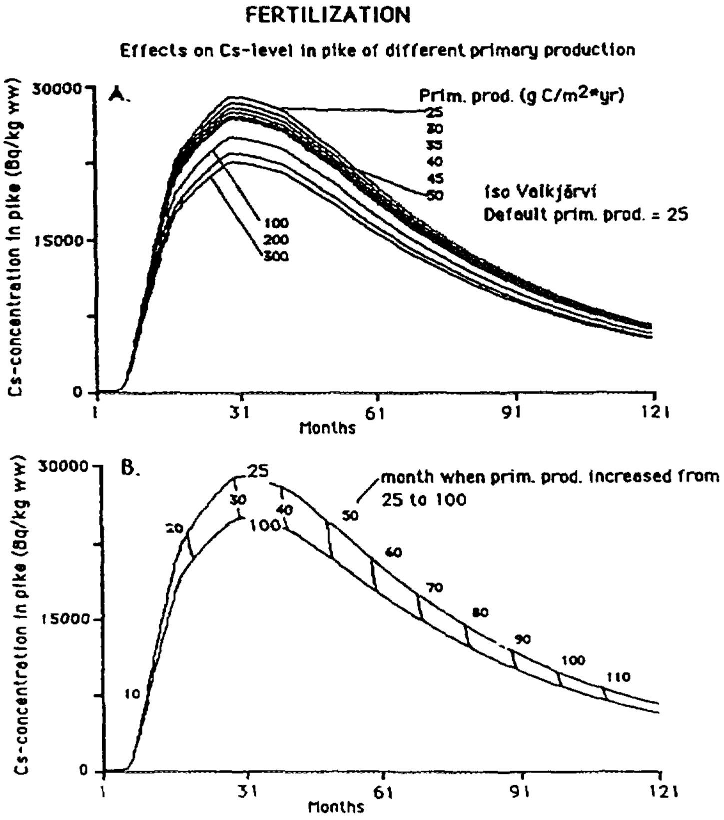


Fig. 6. Simulations illustrating the effect of fertilization on Cs-concentration in pike in Iso Valkjärvi using the VAMP model.

110); and the lowest curve gives the conditions when primary production is set to 100 for the entire period. In the VAMP model, the Cs-concentration in predatory fish is calculated as the ratio between amount of Cs in predator and biomass of predator. The biomass of the predator is calculated from equations driven by input data on primary production. So, in this case, the VAMP model simulates a very quick response to a fertilization, as indicated by the curves linking the upper, default curve to the curve for a primary production of 100.

It is evident that fertilization should NOT be used as a practical remedy in eutrophic lakes.

5. Conclusions

The most important environmental variables regulating the biouptake of radiocesium and the duration (retention time) of the substance in the a lake (i.e., the lake "sensitivity" to radiocesium) are the concentration of potassium in the lake water and the lake water retention time.

Several ecologically acceptable and practically feasible methods exist to remediate a lake contaminated by radiocesium, e.g., liming, potash treatment and fertilization of low-productive lakes. The results of the simulations presented here agree with results obtained from field experiments (V): The sooner the treatment starts, the better, and potash treatment ought to be the most effective remedy.

From the results discussed in this paper some areas of interesting research open up in the future. Models based on the ecosystem approach ought to be developed for target variables (similar to Cs-concentration in water and predatory fish in this work) for many other types of environments, like forests, agricultural land and urban areas. There are problems associated with large ecosystem models in predictive contexts, and also problems with statistical models (IV). The VAMP model used in this work may be considered as a "mixed" model in the sense that it is based on approaches used both in traditional dynamic models and in statistical, regression models. In the future, it is possible that such "mixed" models will be developed and utilized in many practical and scientific situations.

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EVOLUTION OF ^{137}Cs AND ^{90}Sr CONTENT OF THE MAIN FOODSTUFF IN BUCHAREST AREA AFTER THE CHERNOBYL ACCIDENT

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1. INTRODUCTION

Soon after the Chernobyl accident, the radioactive cloud, carrying the nuclides released into the atmosphere, reached Romania and, due to the rainy weather, an important fallout occurred over the Romanian territory. The most important contaminants for Romania were I^{131}, Cs^{134}, Cs^{137} and Sr^{90}. As in many other countries, in the first days, I^{131} had the main contribution to the irradiation dose released to the population. After its decay, and the decay of the other short-lived radionuclides, Cs^{137} and Sr^{90} remained the most important contaminants.

The principal route of intake for these two radionuclides is considered to be the ingestion of contaminated foods. To assess the radioactive burden of foods, a long term, large scale survey was initiated at the National Institute of Hygiene and Public Health (INISP). These results were then used to asses the doses committed due to cesium and strontium intake and the excedentary cancer risk for the population from Bucharest area [1].

2. METHOD AND MATERIALS

Between the end of April 1986 and December 1995, we performed systematic measurements of the radioactive content of foods usually present in the diet of the population: milk, meat (pork and beef), bread, fruits and vegetables.

Radiocesium (Cs^{137} and Cs^{134}) was radiochemically separated using the hexachloroplatinic acid method [2] and Sr^{90} was separated using the fuming nitric acid method [3]. Eventually, Sr^{90} content was measured by his daughter product, Y^{90}. In both cases (cesium and strontium), the radiometric measurements were performed with a low-level anticoincidence beta counting system, with high efficiency.

3. RESULTS

3.1. Cs^{137} content of foods

Due to the important variation of Cs^{137} content of foods since April 1986 until December 1995, we had to split the results in two groups, corresponding to two intervals of time. The intervals in question are the following:

1. April 1986 - December 1987, an interval characterized by high levels of contamination, and
2. January 1988 - December 1995, an interval characterized by lower cesium content and a continuous decrease of its concentration in foods

3.1.1. The high contamination period (April 1986 - December 1987)

Cs^{137} content in different foods, during this interval, is presented in Figures 1 and 2. We have separated the foods in two main groups: vegetal and cereal based products (bread, vegetables and fruits) and animal products (milk, beef and pork).

As it can be seen from Fig. 1, among the vegetal and cereal products, the vegetables had the highest radiocesium content (718 Bq/kg in May 1986), but then decreased to values lower than bread and fruits. Such a result occurred because the vegetables undergone a direct and fast contamination, from the fallout. This justifies the height, the sharpness and the

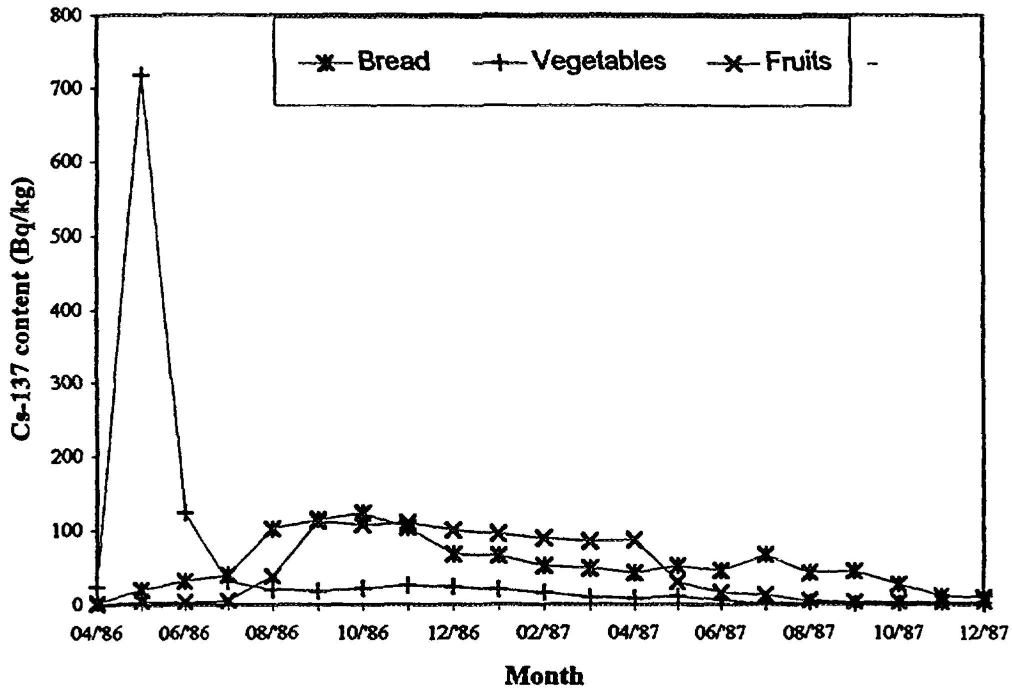

Fig. 1: Cs-137 content in bread, vegetables and fruits, during Apr 86 - Dec 87

position of the contamination peak. By contrast, the bread and the fruits, which were contaminated also from the fallout, but in a phase when the cereals and the fruits were not yet matured, presented much more broader and lower peak, positioned at a larger interval after the accident.

The bread reached its maximum Cs^{137} content in October 1986 (123 Bq/kg), but the peak (the region with content ~ 100 Bq/kg) is quite broad: from August 1986 until December 1986. A second peak, lower and narrower, occurred in July 1987, and was due to the use of flour made out of wheat harvested in 1986.

The fruits presented quite a wide range of cesium content values. Thus, in 1986, the apples and the grapes presented high cesium contents (244.2 and, respectively, 167.8 Bq/kg), while the strawberries had contents ranging between 6 Bq/kg and 68 Bq/kg, depending upon the harvesting place: under the trees or in open field. The nuts had a very high cesium content (240 - 530 Bq/kg), decreasing slowly in the next years. Due to the differences in harvesting periods, the peak for Cs^{137} content in fruits is very wide: from September 1986 until April 1986.

Figure 2 presents the evolution of Cs^{137} content in animal products (milk and meat). All these products are characterized by an indirect contamination (due to the intake of contaminated fodder). Both the milk and the meat exhibit two peaks, the first being a sharp, rather high peak, situated in the interval May 1986 - August 1986, and the second being a broader peak, due to some artificial conditions. The highest cesium content was in beef (563 Bq/kg in June 1986), followed by pork (~285 Bq/kg in July - August 1986 and milk (258 Bq/kg in May 1986). A new peak of cesium content in milk occurs in October 1986 - December 1986, due to the use of milk powder with high radioactive burden added to the pasteurized milk. A similar behavior is exhibited by the meat, which has a new peak during December 1986 - April 1987, due to feeding the animals with fodder harvested in summer 1986.

This behavior of cesium content resulted in a similar behavior of cesium dietary intake of the people from Bucharest. The dietary intake presents three peaks, two of them being due to the fact presented above [4].

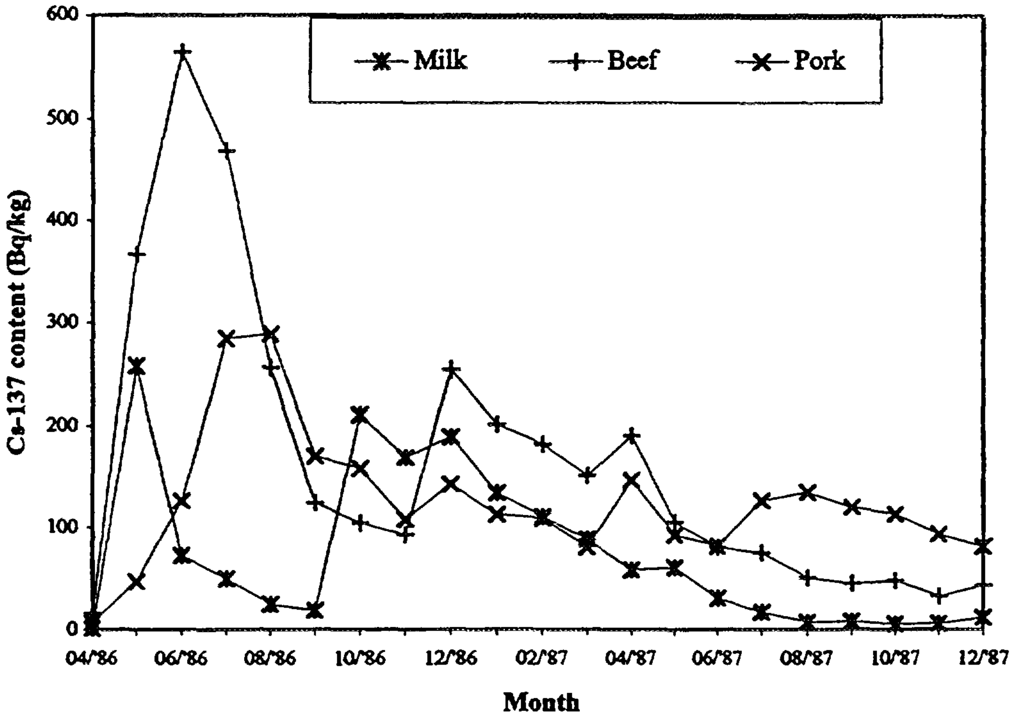

Fig. 2: Cs-137 content in milk and meat, during Apr. 86 - Dec. 87

3.1.2. The period of low cesium content (January 1988 - December 1995)

Figures 3 and 4 present the evolution of cesium content after January 1988. As it can be seen, none of the foods studied present any unexpected evolution. As it can be seen, cesium content is continuously decreasing, and the slope of the decrease is higher in the interval between 1988 and 1989 and smaller afterwards.

3.2. Sr^{90} content of foods

Although Sr^{90} content of foods was not as high as Cs^{137} content, the levels of contamination can be considered as high, if we take in consideration the total absence of radiostrontium from the environmental factors, before the Chernobyl accident.

Figures 5 and 6 present the evolution of strontium content in foods, for the entire period of study. As it can be seen, the peaks are rather narrow, and their position is determined by the path of contamination: a direct and fast contamination for the vegetal products, and an indirect, slow contamination for the animal products. Thus, the first peak occurs for vegetables (immediately after the accident), then for fruits (in the third quarter of 1986) and bread (in the first quarter of 1987), then the meat and the milk (in first and the second quarter of 1987). If we consider the level of contamination, the highest strontium content was in pork (8.43 Bq/kg), followed, in decreasing order, by the bread (7.74 Bq/kg), beef (7.40 Bq/kg), fruits (6.54 Bq/kg), milk (5.54 Bq/kg) and vegetables (3.26 Bq/kg).

3.3. Annual dietary intake

Using the results above, and knowing the dietary habits of the population from Bucharest [5], we were able to calculate the annual Cs^{137} and Sr^{90} dietary intake of the population from Bucharest. In order to asses the intake in the tenth year, we have extrapolated the data we had (until December 1995).

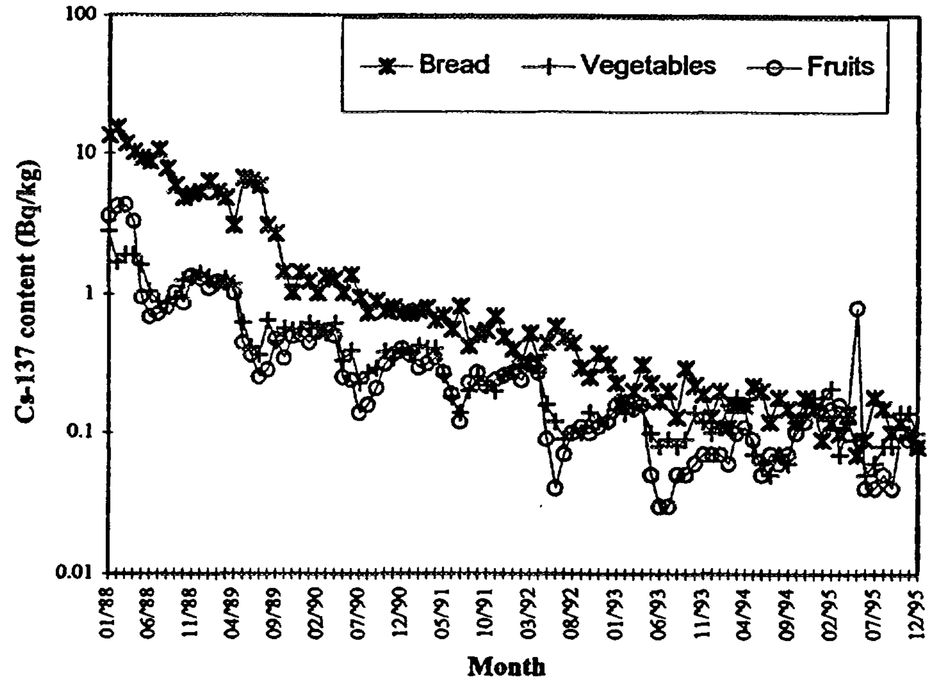

Fig. 3: Cs-137 content in bread, vegetables and fruits, during Jan 88 - Dec 95

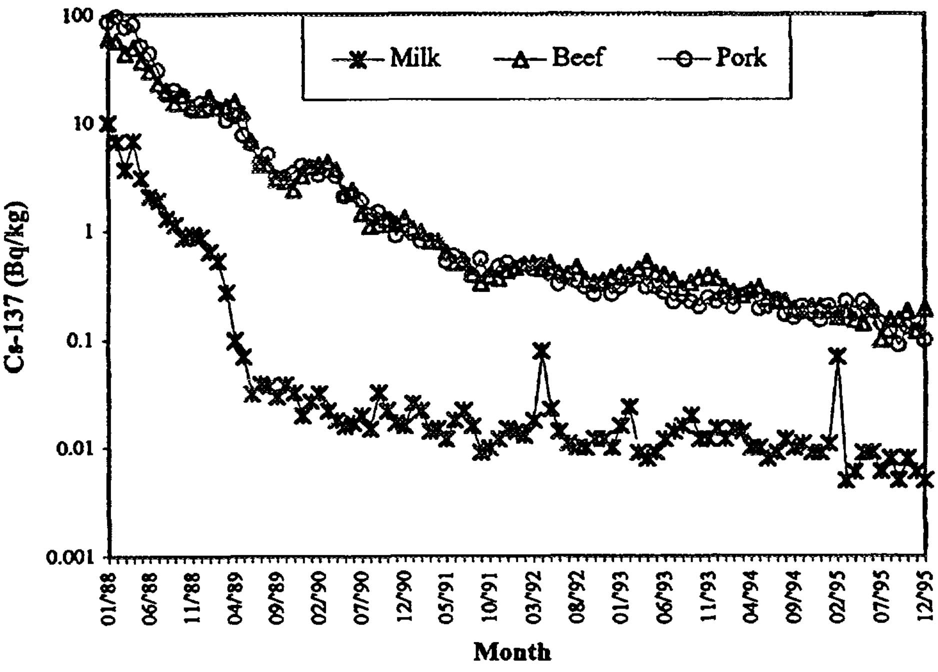

Fig. 4: Cs-137 content in milk and meat, in the interval Jan. 88 - Dec. 95

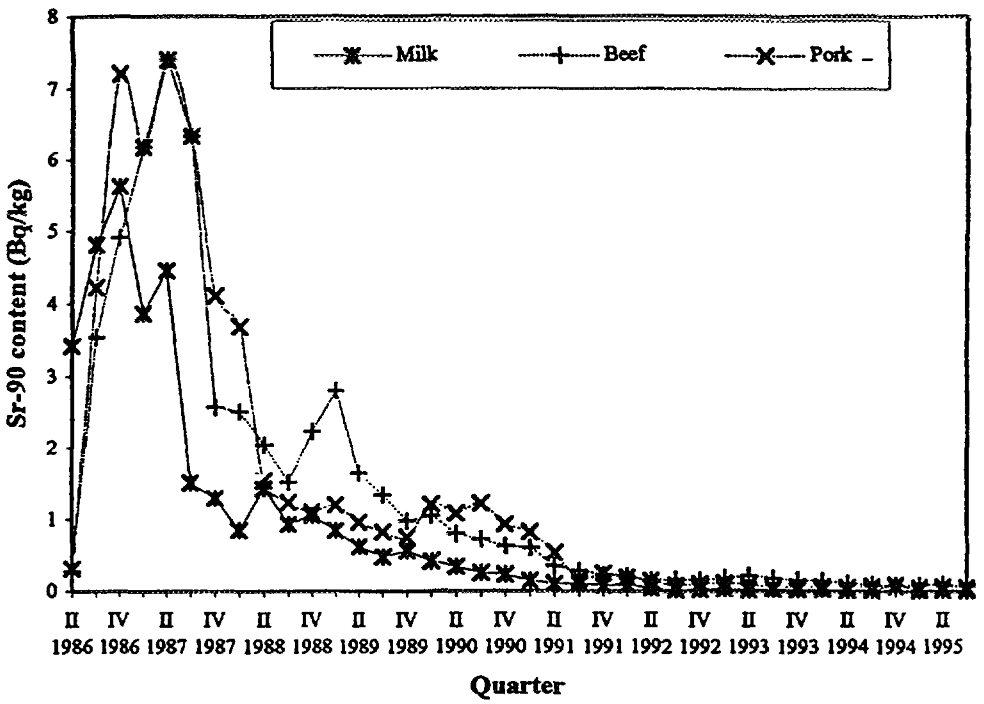

Fig. 5: Strontium content in milk and meat

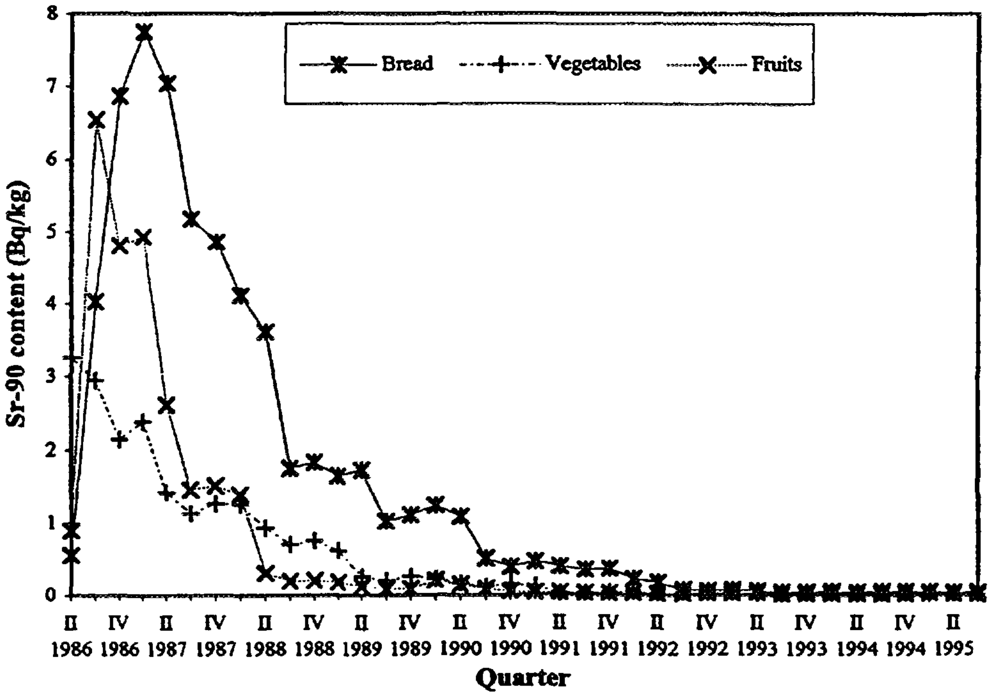

Fig. 6: Strontium content in bread, vegetables and fruits

Figures 7 and 8 present the evolution of the annual Cs^{137} and Sr^{90} dietary intake and, respectively, the percentage from the total intake, in all the ten years elapsed from the accident. (During all these years, the total intake was 19950 Bq Cs^{137} and 1394 Bq Sr^{90}).

As it can be seen from Fig. 7, Cs^{137} annual dietary intake decreased from 8152 Bq in the first year after the accident (April 1986 - March 1987) to 19 Bq in the tenth year after the accident, while Sr^{90} intake decreased from 375 Bq in the first year to 13 Bq in the tenth year. Figure 8 is even more relevant regarding the different slopes of the decrease: while the intake of the first year represents 40.9% of the total intake for radiocesium, radiostrontium intake in the first year represents only 26.9% of the total intake. Furthermore, Cs^{137} intake in the tenth year represents only 0.13% from the total intake, while Sr^{90} intake represents 1.24% of the total intake. Cs^{137} intake decreased faster from the second year until the fifth year, then the decrease was slower, while the slope of the decrease of Sr^{90} intake was rather constant during all ten years (it becomes faster in the last two years).

From the data above, we could tell that only Sr^{90} can be still identified in the environment, Cs^{137} levels of contamination being to low.

4. CONCLUSIONS

After the Chernobyl accident, the aliments from Bucharest area were contaminated with important amounts of Cs^{137} and Sr^{90} The maximum level of contamination (leading to the maximum ingested amount), was recorded in the first year after the accident, for both Cs^{137} and Sr^{90}.

Sr^{90} content of foods decreased slower than Cs^{137} content. Therefore, after ten years from the accident, only Sr^{90} in the aliments may still be a matter for future surveys.

Although after ten years from the Chernobyl accident Cs^{137} and Sr^{90} content in foods is very low, it did not reached yet the values recorded before the accident.

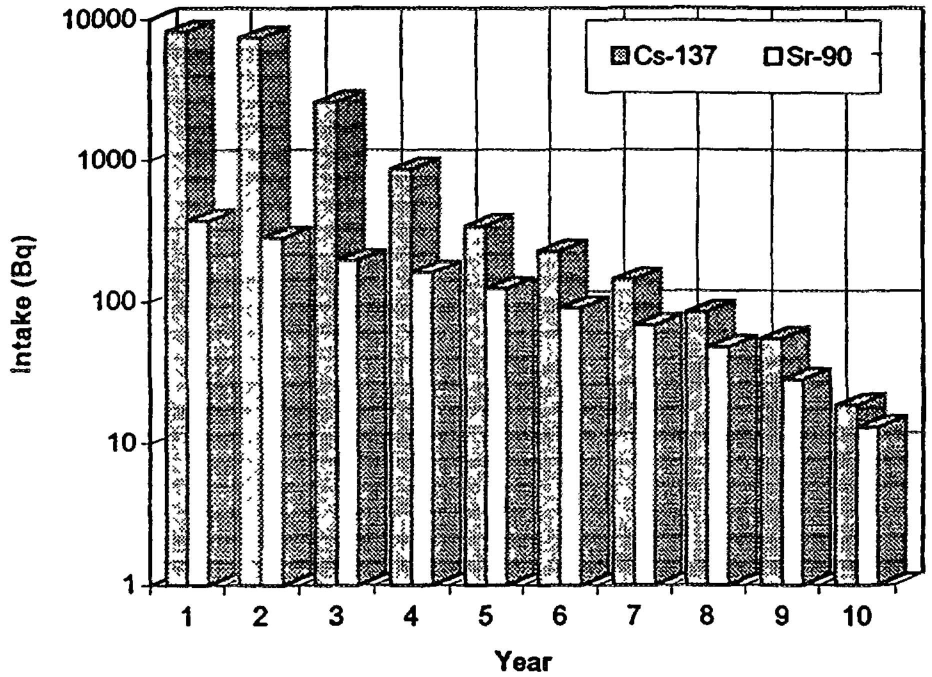

Fig. 7: Annual cesium and strontium intake

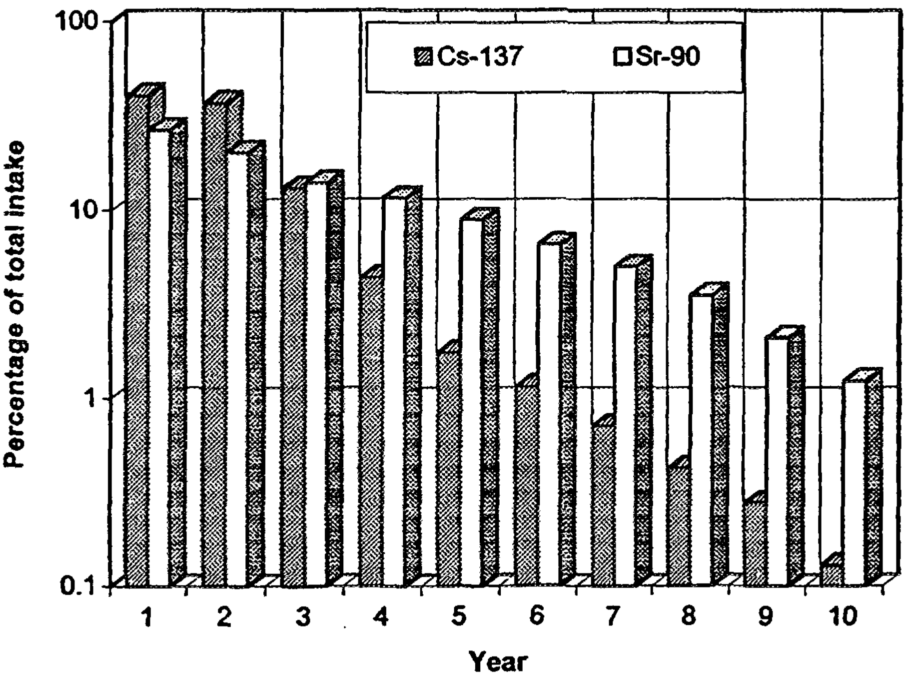

Fig. 8: Procentual annual intake. The values are in percent of total intake

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ASSESSMENT OF ^{90}Sr AND ^{137}Cs ACTIVITY CONCENTRATION IN HUMAN TISSUES IN HUNGARY FOLLOWING THE CHERNOBYL ACCIDENT

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Introduction

Arteficial radioisotope contamination of tissue samples of Hungarian citizens has been regularly monitored by our Institute since 1978. ^{90}Sr concentration of both extracted deciduous teeth and rib samples showed a slight but permanent tendency to decrease since then [1-2]. ^{137}Cs content in the body of Hungarian individuals was monitored by whole body counter from the mid of 60s for about a decade while it became lower of the minimum detection limit (MDL) [3]. It could again be detected by in vivo measurements in May 1986, however, the ^{137}Cs content of human beings in Hungary fell below the detection limit within two years [4]. Thus, the monitoring could only be continued by in vitro measuring of the ^{137}Cs activity concentration in human soft tissue samples [5].

Materials and Methods

Tissue samples were collected from persons who died in Budapest. Rib samples from 389 donors (291 adults and 98 children) were obtained in 1983-1993. Muscle and liver samples were also taken from 91 persons by the Institute of Forensic Medicine of "Semmelweis" Medical University, Budapest in 1988-90.

^{90}Sr concentration in human bone tissue was determined by a radiochemical method according to HASL techniques [6]. Ashed ribs were solved in nitric acid. Activity of ^{90}Y (the daughter nuclide of ^{90}Sr) was detected in an oxalate precipitate by a low background beta analyzer (type TESLA NZR-601). Calcium content of ashed ribs was determined by an atomic absorption spectrometer (type VARIAN AA-175/1b).

As the detection limit of ^{137}Cs content by the whole body counter of our institute was 350 Bq before 1990, the only method to measure a lower ^{137}Cs content in the human body was the detection of ^{137}Cs concentration in soft tissues since spring 1988.

Muscle and liver samples weighing about 100 g were taken from cadavers of both sexes representing age groups from 15 to 75 years, yet, mainly from adults and elderly people. ^{137}Cs contents of samples were measured by a spectrometric analyzer (type NK-360, Gamma Művek, Budapest) with a well-type NaI(Tl) scintillation detector having 150 ml inner volume. Radioactivity of ^{40}K in the samples and of the background were automatically discounted.

Results

^{90}Sr concentration in ribs of adults shows a persistent tendency of decrease during 1983-1993 from about 40 to 20 mBq/gCa. The mean values (and their standard deviations equal to 40-50% of the mean) represent from 12 to 53 donors in each group sampled in a given calendar

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year. There was no change in the tendency of decrease of ^{90}Sr activity concentration in human bones of Hungarian adults in 1986 and the following years - **Figure 1.**

Average values received for different age groups of children sampled following the Chernobyl accident do not differ significantly from those of adults -**Figure 2.**
Ashed bone samples of infants had to be pooled because of their very small mass. In 5 samples of 22 little boys who died prior to the age of 6 months in 1987-90, the ^{90}Sr activity concentration was 21 ± 8 mBq/gCa and in three samples taken from girls of the same age was 33 ± 12 mBq/gCa. In a sample consisting of ribs of 7 girls died at age of 6-12 months a concentration of 51 ± 27, and in a similar age group of 6 little boys 36 ± 16 mBq/gCa was measured - **Table 1.**
Using dose factors of the UNSCEAR [7] the recent radiation dose to the bone marrow is estimated to be as low as 15 μGy/yr which is about 1% of the radiation dose to human bones from natural sources.

^{137}Cs activity concentration in human muscle and liver samples showed a slow decrease in 1988, but a rapid and considerable fall from the beginning of 1989. The proportion of samples with ^{137}Cs content below the minimum detectable level (MDL, which is equal to 0.37 Bq/kg at 50 min counting time) was increasing more or less continuously. The ^{137}Cs activity concentration in all (muscle and liver) samples taken at the end of August 1990 was below MDL, thus, we stopped this type of monitoring - **Table 2.**
Presuming 28 kg muscle and 22 kg of other soft tissues in the organism of a "standard average" adult man [4], the estimated content of ^{137}Cs in the whole body of a Hungarian adult in 1990 was less than 20 Bq. Using the UNSCEAR dose factor [7] - 14 nSv/Bq ^{137}Cs - and data of our measurements a radiation dose equal to about 5 μSv in 1988, 1 μSv in 1989 and less than 0.5 μSv in 1990 was calculated.

Conclusion

According to these data it may be concluded that we could detect no increase in ^{90}Sr concentration of human bones - including the developing bones of newborns and small children - after the Chernobyl reactor accident.

On the basis of ^{90}Sr and ^{137}Cs activity concentrations measured in human tissues of Hungarian citizens following the Chernobyl accident it can also be concluded that they may not cause any harm to health - according to our present knowledge - as they might produce a radiation dose lower than the standard deviation of the average annual effective dose equivalent received from natural sources within Hungary.

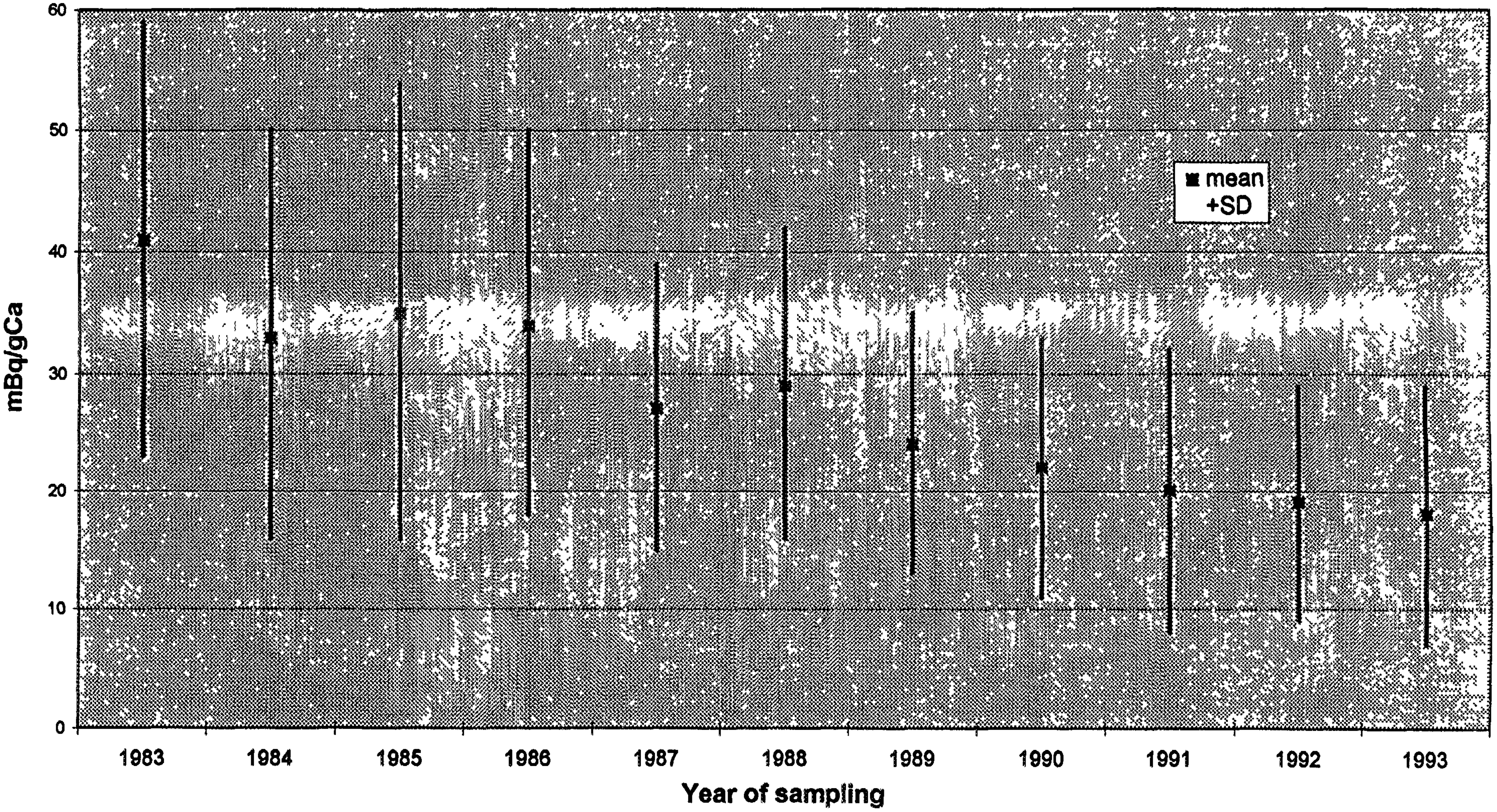

Figure 1: Activity concentration of ^{90}Sr in bones of Hungarian adults, mBq/gCa, 1983 to 1993

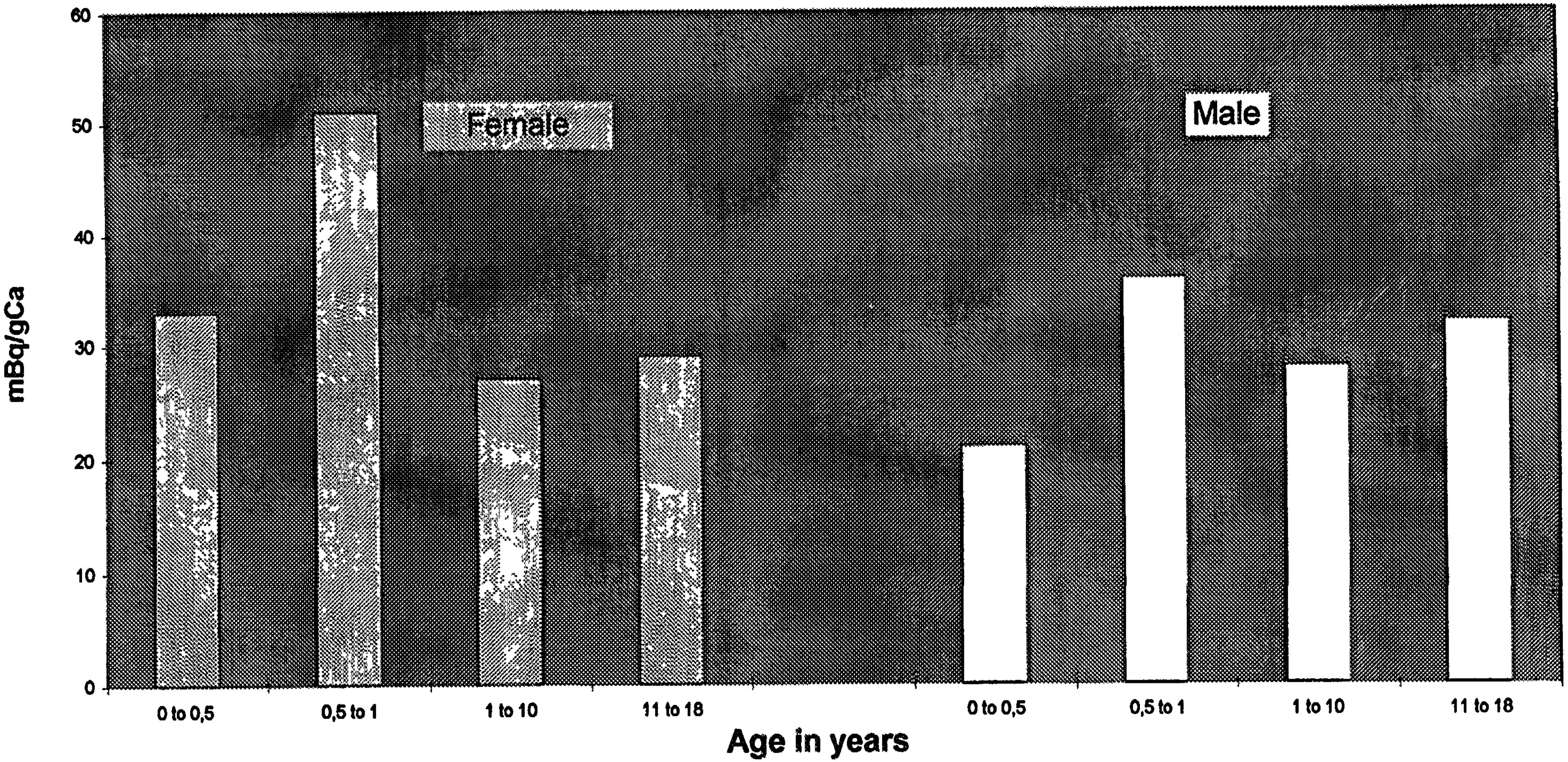

Figure 2. Activity concentration of ^{90}Sr in bones of Hungarian children, mBq/gCa, 1987-1990

TABLE 1.

^{90}Sr concentration in bones of Hungarian children, mBq/gCa, 1987-90

Sex	Female		Male	
Age, years	No. of donors	Mean ± SD	No. of donors	Mean ± SD
0 - 0.5	(11)	33 ± 12	(22)	21 ± 8
0.5 - 1	(7)	51 ± 27	(6)	36 ± 16
1 - 10	(10	27 ± 12	(16)	28 ± 12
11 - 18	(11)	29 ± 14	(15)	32 ± 12

TABLE 2.

Dynamics of ^{137}Cs activity concentration in human tissues in 1988-90 in Hungary

Date of sampling	^{137}Cs concentration of human tissues, Bq/kg				
	No. of donors	Muscles		Liver	
		No. of samples below MDL	Mean ± SD	No. of samples below MDL	Mean ± SD
1988					
May, 3	5	0	7.8±3.9	2	4.1±1.3
August, 5	5	1	7.7±4.4	5	<0.37
September 16	5	0	5.2±4.6	1	2.8±1.4
November, 18	10	2	4.1±3.5	7	1.4±1.6
1989					
February, 28	5	4	0.68±0.68	2	1.4±0.95
May, 15	10	6	1.8±1.1	5	1.8±1.4
August, 9	15	10	1.0±1.1	12	1.4±2.3
November, 20	7	4	1.7±2.1	3	1.8±2.2
1990					
February, 20	9	6	0.82±0.84	8	0.48±0.36
May, 26	10	9	0.62±0.79	9	0.40±0.10
August, 28	10	10	<0.37	10	<0.37

Note: MDL - minimum detectable level (0.37 Bq/kg)

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HONEY-DEW HONEY AS A LONG TERM INDICATOR OF ^{137}Cs POLLUTION

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1. Introduction

^{137}Cs, produced as a by-product of the atmospheric testing of thermonuclear weapons during the period extending from the 1950s to the 1970s, was distributed globally within the stratosphere and deposited as wet and/or dry fallout. The last great amount of radioactive caesium was deposited on the earth surface after Chernobyl accident. Significant variations in caesium activity levels in soils are caused by Chernobyl-derived fallout with relatively short period of contamination and great variabilities in activity and/or quantity of rainfall. However, total weapon testing-derived caesium pollution can be treated as generally uniform, *i.e.*, numerous events over an extended period that minimise any local variation.

Deposited caesium penetrates from the soil surface very slowly into deeper layers with water [1]. The ^{137}Cs migration rate can be retarded by sorption processes. The relative abundance of clay and mica minerals, particularly illte, results in the rapid and nearly irreversible caesium immobilisation in top soil layer [2]. Meanwhile, caesium, as well as the other radionuclides that behave like cations, can be moved upward by plant's uptake depending on various factors: plant species, sorption and desorption processes in soil, mineral soil composition, grain size and soil types, lateral caesium migration, *etc.* Certain plant species are known as caesium pollution indicators, but the uptake by an individual plant can be very different. In the first place, it depends on the presence of free caesium in species root system zone and competitive effects of potassium [3, 4, 5]. Different soil types show differences in the ratio of sorbed to fixed caesium, in soil size fractions, in pH value, content of organic matter, as well as in ^{137}Cs vertical distribution profiles and, consequently, in caesium transfer from soil to plants [6, 7, 8, 9]. Even after the relatively homogeneous contamination, all these factors could vary in the wide range locally and the representative quality of any single point-sample could be questionable few years after the contamination.

Honey bees and their products have been used as indicators and monitors of a variety of environmental pollution because of their ability to reflect the immediate environment condition [10, 11]. The maximum area covered by honey bees in their nectar-gathering process can be represented by a circle with radius of few kilometres in which the numerous different factor could be included. Depending on previously mentioned factors as well as on honey bee pasture type, ^{137}Cs appears in various types of honey [12, 13, 14]. Heather plants, *Calluna vulgaris* especially, is known species as the indicator of caesium pollution [15, 16], even health hazards associated with the ingestion of heather honey cannot be ignored. Significant differences in activity and long-term behaviour of ^{137}Cs were found between nectar honey and honey-dew honey. The trend towards decreasing value of ^{137}Cs activity in bush/tree and meadow nectar honey types was documented on samples collected in years after Chernobyl accident [13, 17]. Meanwhile, ^{137}Cs activities in heather honey and honey-dew honey are significantly higher than in nectar honey types [13, 16]. Caesium in heather honey and honey-dew honey is relatively easy detectable long time after contamination.

Honey-dew appears on deciduous trees sporadically, and coniferous wood dominantly. Conifers are inhabited by insects Homoptera, among which leaf-lice and shield-shaped-lice prevail. Conifers are inhabited mainly by green fir-lice (*Cinaria pectinatae*), and *C. pilicornis, C. viridescens, Lachnus grossus* or *L. piceae* can be found frequently. Rarely, shield-shaped-lice like *Physokermes piceae* or *P. hemycryphus* can be found on the coniferous tree, also. These insects pierce the youngest branches and the needles of coniferous trees in food search. In fact, honey-dew is the secretion of these insects.

In their food-gathering process, honey bees collect honey-dew. ^{137}Cs activity measurements in different honey types were used to determine the indicator capability of the specific plant, and to follow the behaviour and the fate of caesium in the environment. In our current research of honey-dew, preliminary results of which are partly presented in paper, in Gorski Kotar area, Croatia, we have broaden our investigation to the caesium content in soil, fir growth ring and bark, fir and spruce branches and needles. It was necessary, because the question wherefrom caesium arises is still opened one. The fact that collected honey samples nearly always are various mixtures of nectar-meadow honey (or bush/tree-nectar honey) and spruce honey-dew honey and fir honey-dew honey represents the great difficulty in research. However, it seems that the sample of honey-dew honey could be one of the best random samples that is representative for the broader area, generally.

2. Sampling and measurement

2.1. Samples of honey

Since 1993, samples of honey are ordinarily collected in early autumn from Gorski Kotar area, Croatia. Honey samples were collected mechanically, by extracting honey from combs. Control long-time series of various types of honey-dew honey and heather honey is collected in Austria, Germany and Slovenia. Control series of pollen honey types was collected in period 1990-1994 in Croatia. Honey types (heather, nectar, honey-dew or mixed honey) were identified on the basis of pollen analyses and electroconductivity measurement. Pollen analizes of honey were done according [18]. Activities of ^{137}Cs and ^{40}K in determined honey samples, placed in counting vessels of 125 cm^3 volume and known geometry, were measured by gamma-spectrometric method.

2.2 Samples of coniferous tree

Fir bark, growth ring, branches and needles are taken from cutted individual fir-trees. Growth ring and bark were taken from wood segment that was cutted at 9 m above ground. Branches (including accompanying bark) and needles were taken as composites from whole height of tree. Caesium mobility in the youngest part of tree-branches is followed by sampling of 15 marked trees of fir and spruce (branches up to 6 m above ground are annually cutted) at each of observed locations. All wood-samples were dried at 105^0 C to the constant weight, homogenised, stored in counting vessels of 125 cm^3 volume and known geometry, and measured by gamma-spectrometric method.

2.3. Gamma-spectrometric method

The activities of ^{137}Cs and ^{40}K were determined by gamma-spectrometric method using low background HPGe semiconductor detector system coupled to a 4096 channel analyser. Depending on sample mass and activity, spectra were recorded for times ranging from 80,000 and 150,000 seconds. Activities of ^{137}Cs and ^{40}K were calculated from the 661.6 keV-peak and the 1460.7 keV-peak, respectively. The spectra were analysed with personal computer using GENIE PC Canberra software. Activities of ^{137}Cs in honey samples were recalculated on the July 1, of each year of sample collection. Caesium activities in samples of coniferous wood were recalculated on the day of sample's collection. Single counting error at respective radioactivity level was taken as detection limit.

3. Results and discussion

Significant differences in activity and long-term behaviour of ^{137}Cs were found between nectar honey and honey-dew honey. The trend towards decreasing value of ^{137}Cs activity in bush/tree and meadow nectar honey types was documented on samples collected in period 1990-1994 in Croatia (Table I). Meanwhile, ^{137}Cs activities in honey-dew honey are significantly higher than in nectar honey types. In numerous honey-dew honey samples collected from 1993 to 1995 in Gorski Kotar, Croatia, caesium was found in relatively high concentrations (Table II) - more than tenfold higher than in nectar honey from Croatia in the respective year.

Table I. ^{40}K and ^{137}Cs (Bq/kg) in nectar honey types (mixed, meadow or bush/tree honey) collected between 1990 and 1994 in Croatia

Year	Number of samples	^{40}K		^{137}Cs	
		Range	Average	Range	Average
1990	9	18.8 - 30.1	24.9 ± 3.6*	0.5 - 7.9	4.0 ± 2.4
1991	16	16.2 - 33.2	24.6 ± 4.6	0.4 - 3.9	1.9 ± 1.1
1992	11	18.7 - 29.5	24.5 ± 4.0	0.4 - 1.2	0.7 ± 0.3
1993	17	17.3 - 45.4	27.8 ± 9.0	0.2 - 0.9	0.5 ± 0.2
1994	20	13.8 - 41.9	27.4 ± 10.1	0.0 - 0.7	0.3 ± 0.2

* standard deviation of 1 σ

The ^{137}Cs determination in predominantly spruce honey-dew honey samples, collected in period 1952-1994 in cca 25 km radius circle around Lunz am See, Austria, indicates caesium fallout peaks (Table III). The significant decrement of activity has not been observed relatively long time after fallout peaks from weapon testing and Chernobyl. Similar ^{137}Cs behaviour was found in different (heather, honey-dew, mixed honey-dew) honey samples collected in Germany (Table III), as well as in mixed honey-dew honey samples collected in period 1987-1995 in Slovenia (Table IV).

The results of ^{137}Cs activity measurement in fir bark, branches and needles are presented in Table V. The increasing trend of ^{137}Cs activities in younger *vs.* older fir-branches and fir-needles, independent on caesium content in soil and soil type, was found in samples at all sampled location. The highest caesium activity was found in fir-branches, fir-needles, bark and the youngest growth ring. Caesium activities in the youngest parts of fir branches are higher than in corresponding fir needles, generally.

As distinguished from the French white fir growth ring [19], in fir cutted at Milanov vrh (Table VI), in growth rings which growth before approximately 1925, caesium was not found. However, the similar radial ^{137}Cs distribution in both fir trees is opposite to ^{137}Cs distribution in the sugi tree rings harvested from Japan [20].

Table II. ^{40}K and ^{137}Cs (Bq/kg) in mixed (honey-dew and meadow) honey collected in 1993, 1994 and 1995 in Gorski Kotar area, Croatia

Location	^{40}K	^{137}Cs	Honey type
1993 year			
Delnice (1)	104.4 ± 13.6*	25.7 ± 0.4	mixed honey-dew / meadow
Delnice (2)	98.0 ± 13.3	25.8 ± 0.4	mixed honey-dew / meadow
Gerovo (1)	110.1 ± 13.8	47.6 ± 0.6	mixed honey-dew / meadow
Gerovo (2)	78.9 ± 13.2	19.5 ± 0.4	meadow / mixed honey-dew
Gerovo (3)	94.4 ± 13.4	17.2 ± 0.4	meadow / mixed honey-dew
Crni lazi	96.1 ± 13.4	31.5 ± 0.5	mixed honey-dew / meadow
Milanov vrh (1)	83.2 ± 13.5	17.2 ± 0.4	meadow / fir honey-dew
Milanov vrh (2)	91.7 ± 13.5	14.7 ± 0.3	meadow / fir honey-dew
Kozji vrh	19.1 ± 2.6	15.4 ± 0.4	meadow / mixed honey-dew
Fužine (1)	98.6 ± 13.6	38.6 ± 0.5	mixed honey-dew / meadow
Fužine (2)	38.5 ± 3.2	0.9 ± 0.1	meadow
Fužine (3)	92.0 ± 13.5	4.6 ± 0.2	meadow // mixed honey-dew
Brod Moravice	82.5 ± 13.5	6.0 ± 0.2	meadow // mixed honey-dew
Sunger	89.5 ± 13.6	19.9 ± 0.4	meadow / mixed honey-dew
Lividraga	138.4 ± 13.4	36.2 ± 0.5	mixed honey-dew / meadow
1994 year			
Fužine (1)	114.3 ± 13.3	17.7 ± 0.4	meadow / mixed honey-dew
Fužine (2)	74.4 ± 13.6	18.1 ± 0.4	meadow / mixed honey-dew
Fužine (3)	103.7 ± 13.6	13.7 ± 0.3	meadow / mixed honey-dew
Fužine (4)	142.5 ± 13.5	15.9 ± 0.4	meadow / mixed honey-dew
Sunger	109.0 ± 13.7	21.2 ± 0.4	meadow / mixed honey-dew
Crni lazi	128.4 ± 13.7	13.5 ± 0.3	meadow / mixed honey-dew
Kozji vrh	46.5 ± 13.3	2.6 ± 0.3	meadow // mixed honey-dew
Sušica	85.1 ± 13.3	5.1 ± 0.2	meadow // mixed honey-dew
Delnice	90.2 ± 13.4	21.5 ± 0.4	meadow / mixed honey-dew
Skrad	117.5 ± 13.8	4.8 ± 0.2	meadow // mixed honey-dew
Lič	143.0 ± 13.9	11.8 ± 0.3	mixed honey-dew / meadow
1995 year			
Gerovo (1)	84.9 ± 13.6	13.3 ± 0.3	meadow / mixed honey-dew
Gerovo (2)	76.1 ± 13.3	4.2 ± 0.2	meadow // mixed honey-dew
Razloge	102.6 ± 13.5	12.6 ± 0.3	meadow / mixed honey-dew
Sunger (1)	34.0 ± 13.9	3.8 ± 0.2	meadow // spruce honey-dew
Sunger (2)	22.2 ± 13.7	1.9 ± 0.1	meadow // spruce honey-dew
Sunger (3)	25.2 ± 13.4	4.0 ± 0.2	meadow // spruce honey-dew
Mrkopalj	13.3 ± 13.0	0.8 ± 0.1	meadow
Litorić	75.0 ± 3.6	11.4 ± 0.3	meadow / mixed honey-dew
Sušica	90.2 ± 3.8	19.7 ± 0.4	mixed honey-dew / meadow

* counting error; / first component prevails; // second component is traceable

Table III. ^{137}Cs (Bq/kg) in predominantly spruce honey-dew honey collected between 1952 and 1994 in cca 25 km radius circle around Lunz am See, Austria, and honey from Germany, collected between 1965 and 1995.

AUSTRIA		GERMANY		
Year	^{137}Cs	Year	^{137}Cs	Honey type
1952	0.0 ± 0.4*	1965	19.9 ± 0.6	honey-dew
1956	0.0 ± 0.4	1965	14.0 ± 0.5	honey-dew
1956	1.7 ± 0.4	1965	0.7 ± 0.2	honey-dew
1956	1.9 ± 0.4	1966	447.0 ± 2.7	heather
1961	2.8 ± 0.4	1968	238.1 ± 1.9	heather
1964	19.4 ± 0.6	1969	176.1 ± 1.6	heather
1968	42.1 ± 0.8	1975	23.9 ± 0.5	honey-dew
1968	7.4 ± 0.4	1977	320.1 ± 1.9	heather
1969	31.0 ± 0.6	1977	125.4 ± 1.2	heather
1969	12.9 ± 0.5	1986	6.4 ± 0.3	honey-dew
1976	1.1 ± 0.2	1987	10.5 ± 0.3	honey-dew
1977	3.0 ± 0.3	1987	180.1 ± 1.5	heather
1978	11.7 ± 0.4	1987	32.3 ± 0.5	honey-dew
1980	9.8 ± 0.3	1987	36.4 ± 0.8	honey-dew / meadow
1984	5.9 ± 0.3	1988	112.8 ± 1.3	honey-dew / meadow
1986	44.7 ± 0.6	1988	4.7 ± 0.5	honey-dew
1986	194.8 ± 1.2	1990	3.9 ± 0.2	honey-dew
1987	51.1 ± 0.6	1991	7.2 ± 0.3	meadow / honey-dew
1989	14.7 ± 0.4	1991	93.4 ± 1.3	heather
1990	37.9 ± 0.5	1992	2.2 ± 0.2	meadow / honey-dew
1993	13.4 ± 0.3	1993	1.1 ± 0.1	meadow / honey-dew
1994	69.2 ± 0.7	1995	11.0 ± 0.3	honey-dew / meadow

* counting error

Table IV. ^{40}K and ^{137}Cs (Bq/kg) in mixed (honey-dew and meadow or chestnut) honey collected between 1987 and 1995 in Slovenia

Year	^{40}K	^{137}Cs	Honey type
1987	67.3 ± 3.6*	8.3 ± 0.3	meadow // fir honey-dew
1988	154.2 ± 4.7	41.8 ± 0.6	spruce honey-dew / chestnut
1988	80.3 ± 3.7	10.4 ± 0.3	meadow // fir honey-dew
1989	76.0 ± 3.7	35.6 ± 0.5	meadow / spruce honey-dew
1990	110.4 ± 4.4	50.6 ± 0.7	spruce honey-dew / meadow
1991	116.1 ± 4.2	42.7 ± 0.6	fir honey-dew / meadow
1991	95.9 ± 4.0	49.0 ± 0.6	spruce honey-dew / chestnut
1992	58.3 ± 3.4	3.7 ± 0.2	chestnut / meadow
1993	121.5 ± 4.2	13.6 ± 0.3	chestnut / spruce honey-dew
1994	75.9 ± 3.7	35.5 ± 0.5	meadow / spruce honey-dew
1995	97.5 ± 4.0	3.5 ± 0.2	meadow // spruce honey-dew
1995	93.2 ± 3.9	20.6 ± 0.4	meadow / fir honey-dew

* counting error; / first component prevails; // second component is traceable

Table V. ^{137}Cs (Bq/kg) in fir bark, needles and branches from Gorski Kotar, Croatia (fir trees were cutted in September 1994)

Year	MILANOV VRH		LIVIDRAGA		LIČ	
	Branches	Needles	Branches	Needles	Branches	Needles
Bark	15.1±0.5		24.0±0.6		45.1±0.5	
1994	30.1±1.1*	22.0±1.0	133.3±3.2	73.9±1.7	144.7±3.6	90.8±1.9
1993	18.2±0.9	12.4±0.8	53.1±1.7	46.0±1.3	49.8±1.6	43.2±1.3
1992	11.7±0.7	8.8±0.7	29.5±1.1	25.9±1.0	45.4±1.4	43.3±1.3
1991	11.3±0.6	8.2±0.7	26.0±1.1	25.9±1.0	32.9±1.2	38.1±1.1
1990	11.5±0.7	10.3±0.7	18.4±0.8	27.6±1.1	22.0±0.9	36.0±1.2
1989	11.4±0.6	6.6±0.5	15.6±0.8	27.0±1.3	17.5±0.8	34.5±1.2
1988	10.6±0.6	n.a.*	15.4±0.8	26.8±1.6	17.4±0.8	37.8±1.3
1987	12.1±0.7	n.a.	14.5±0.8	n.a.	17.5±0.8	38.6±1.6
1986	11.6±0.6	n.a.	14.4±0.8	n.a.	16.2±0.8	n.a.
1985	14.5±0.7	n.a.	15.8±0.8	n.a.	17.8±0.8	n.a.

* - sample not available

Table VI. ^{40}K and ^{137}Cs (Bq/kg) in fir growth ring from Gorski Kotar, Croatia (fir trees were cutted in September 1994)

Period	CRNI LAZI		Year	LIČ	
	^{40}K	^{137}Cs		^{40}K	^{137}Cs
Bark	71.3±5.5*	15.6±0.5	Bark	135.2±4.0	45.1±0.5
1980-1994	30.4±6.1	2.8±0.4	1994	72.3±6.1	8.3±0.5
1970-1979	25.4±5.5	0.9±0.3	1993	46.3±4.1	4.4±0.3
1960-1969	23.4±5.5	1.0±0.3	1992	40.2±3.4	5.7±0.3
1950-1959	28.2±5.8	0.6±0.3	1991	35.5±3.8	4.3±0.3
1940-1949	28.2±5.8	0.5±0.3	1990	30.0±3.4	3.7±0.2
1930-1939	47.4±6.3	0.5±0.3	1989	25.2±3.3	1.9±0.2
1920-1929	46.3±5.8	0.3±0.3	1988	23.6±3.6	0.7±0.2
1910-1919	61.8±6.7	b.c.e.**	1987	24.5±3.9	0.8±0.2
1900-1909	51.2±5.8	b.c.e.	1986	21.5±4.0	0.6±0.3
1890-1899	48.1±6.0	b.c.e.	1985	19.4±4.2	0.6±0.3
1880-1889	32.2±5.7	b.c.e.	1984	20.3±3.4	0.8±0.2
1860-1879	51.2±6.5	b.c.e.	1983	21.1±3.5	0.8±0.2
1820-1859	55.3±6.6	b.c.e.			

* - counting error; ** - below counting error

Surprisingly, the increasing trend of ^{137}Cs activities in the youngest *vs.* one year older fir branches and needles were found at all sampled location (Table VII). That fact indicates relatively high caesium mobility in the youngest part of fir tree branches. Meanwhile, it seems that ^{137}Cs migrates from a few years old parts of fir branches to theirs the youngest top.

4. Conclusions

^{137}Cs activity measurements in different honey types and in distinctive parts of the long-live coniferous plants were used to determine the indicator capability of the specific plant, and to follow the behaviour and the fate of caesium in the environment. Based on the preliminary results of current research, the following conclusions were obtained concerning ^{137}Cs:

Table VII. ^{137}Cs (Bq/kg) in fir and spruce needles and branches sampled in December 1994 (A) and September 1995 (B) - each sample is composite of 15 trees

Location	Fir (branches + needles)			Spruce 1995*(B)	
	1994*(A)	1994*(B)	1995*(B)	Branches	Needles
Crni lazi	19.4 ± 0.7	12.8 ± 0.4	21.7 ± 0.5	31.5 ± 0.9	20.8 ± 0.5
Milanov vrh	35.5 ± 1.0	25.2 ± 0.6	51.6 ± 0.8	36.4 ± 1.0	24.7 ± 0.6
Brloško	52.1 ± 1.1	32.0 ± 0.6	86.4 ± 1.0	10.9 ± 0.4	6.2 ± 0.3
Suha rečina	15.0 ± 0.6	16.5 ± 0.5	40.0 ± 0.7	12.0 ± 0.6	8.2 ± 0.3
Zalesina	15.5 ± 0.6	14.9 ± 0.5	27.6 ± 0.6	14.1 ± 0.6	8.2 ± 0.3
Lividraga	38.4 ± 1.1	36.7 ± 0.7	70.9 ± 0.9	24.6 ± 0.7	20.0 ± 0.5

* - year of growth

(1) Relatively high ^{137}Cs activities found in honey-dew honey long time after caesium contamination peaks, more than tenfold higher than in nectar honey from the respective years, suggests than honey-dew honey could be used as the indicator of ^{137}Cs pollution very long time after the contamination. Meanwhile, honey-dew honey is probably one of the best random samples, which is representative for the broader area covered by coniferous forests.

(2) Caesium activity measurements in distinctive parts of the long-live coniferous plant (spruce-tree and fir-tree) grooved after 1986 shows relatively high caesium activities. There seems that spruce and fir, their youngest branches and needles especially, could be used as indicators of caesium pollution also.

(3) Relatively long time after contamination, mobility of ^{137}Cs in youngest fir tree branches and needles is high. Question wherefrom caesium arises is still opened one, because up to the present collected samples and analysed data are still insufficient for answer.

Acknowledgement: Authors wish to express their gratitude to dr. Helmut Horn, University of Hochenheim, Landesanstalt fuer Bienenkunde, Germany, and to dr. Janez Poklukar, Kmetijski institute Ljubljana, Slovenia, for the collected honeys from Germany and Slovenia. This research is partly financed by Ministry of science and technology, Republic of Croatia and through U.S.-Croatian science/technology program - project: 'Honey bees and their products as a indicator of environmental caesium pollution".

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METHODS OF EVALUATING THE POTENTIAL FOR REHABILITATION OF LAND POSING A RADIATION HAZARD AND ITS RETURN TO AGRICULTURAL USE

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МЕТОДИЧЕСКИЕ АСПЕКТЫ ОЦЕНКИ ПОТЕНЦИАЛЬНОЙ РЕАБИЛИТАЦИИ РАДИОАКТИВНО-ОПАСНЫХ ЗЕМЕЛЬ И ИХ ВОЗВРАТА В СЕЛЬХОЗПРОИЗВОДСТВО

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После катастрофы на Чернобыльской АЭС на территории Беларуси к категории радиационно опасных земель относятся земли, расположенные в зонах радиоактивного загрязнения на которых не обеспечивается производство продукции, содержание радионуклидов в которой не соответствует республиканским нормам.

К категории радиационно опасных земель (РОЗ) относятся земельные участки, загрязненные:

цезием-137	от 40	Ки/кв.км и более;
стронцием-90	от 3	Ки/кв.км и более;
плутонием-238,239,240	от 0,1	Ки/кв.км и более;

а также земли с меньшей плотностью загрязнения, где невозможно обеспечить получение чистой продукции.

В перый период после катастрофы значительное количество сельскохозяйственных земель, подвергшихся радиоактивному загрязнению, было выведено из использования. В настоящее время проводятся работы по оценке потенциальной возможности реабилитации этих земель.

Оценка потенциальной возможности реабилитации базируется на:

1. Детальном обследовании радиационной обстановки на каждом участке с определением полного запаса радионуклидов;
2. Описании специфики почвенного покрова;
3. Определении агрохимических свойств;
4. Прогнозе загрязнения сельхозпродукции (по культурам) на основании данных о радиоактивном загрязнении почв и их физики-химических и агрохимических свойств.

При проведении работ по реабилитации земель используются следующие критерии:

КРИТЕРИИ ДЛЯ ВВОДА В КАТЕГОРИЮ РО:

1. Запас радионуклидов в почве составляет 40 Ки/кв.км и более по цезию-137, 3 Ки/кв.км и более по стронцию-90, 0,1 Ки/кв.км и более по плутонию - 238,239,240 на момент обследования с использованием "Методических указаний по радиационному обследованию земель, выведенных из землепользования в результате катастрофы на ЧАЭС, с целью их последующей реабилитации".
2. Получение продукции не соответствующей республиканским нормам.

КРИТЕРИИ ДЛЯ ВЫВОДА ИЗ КАТЕГОРИИ РО:

1. Запас радионуклидов в почве составляет менее 40 Ки/кв.км по цезию-137, более 3 Ки/кв.км по стронцию-90, более 0,1 Ки/кв.км по плутонию - 238,239,240 на момент обследования с использованием "Методических указаний по радиационному обследованию земель, выведенных из землепользования в результате катастрофы на ЧАЭС, с целью их последующей реабилитации".
2. Прогноз загрязнения продукции с использованием действующей на момент обследованиея методики прогнозирования;
3. Оценка соответствия прогнозируемого загрязнения действующим на момент обследования республиканским нормам;
4. Сравнение прогнозируемых величин загрязнения продукции с реальными уровнями (например, на кормовых угодьях).
5. Оценка потенциальной возможности снижения уровня радиоактивного загрязнения продукции до допустимых уровней путем применения специальных мероприятий.

MIGRATION AND FORECAST OF THE RADIOACTIVE CONTAMINATION OF THE SOIL, WATER AND AIR ON THE TERRITORY OF BELARUS AFTER THE ACCIDENT AT THE CHERNOBYL NPP

XA9745811

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1.INTRODUCTION

The accident at the Chernobyl NPP is the largest technogenic accident of our epoch, the global consequences of which for whole manhind with the course of time will larger and larger significance.

In spite of the fact, that the radioactive contamination owing to the Chernobyl accident affected the whole world, just Belarus was subjected to the most intensive radioactive contamination. In addition the radioactive contamination territory of Belarus more than 37 kBq/sq.m. by caesium-137 has made 23 % from the whole of the Republic. At the same time as a result of the Chernobyl accident, 5,0 % of a territory of the Ukraine and 0,6 % of Russia have been contaminated with radionuclides (fig.1).

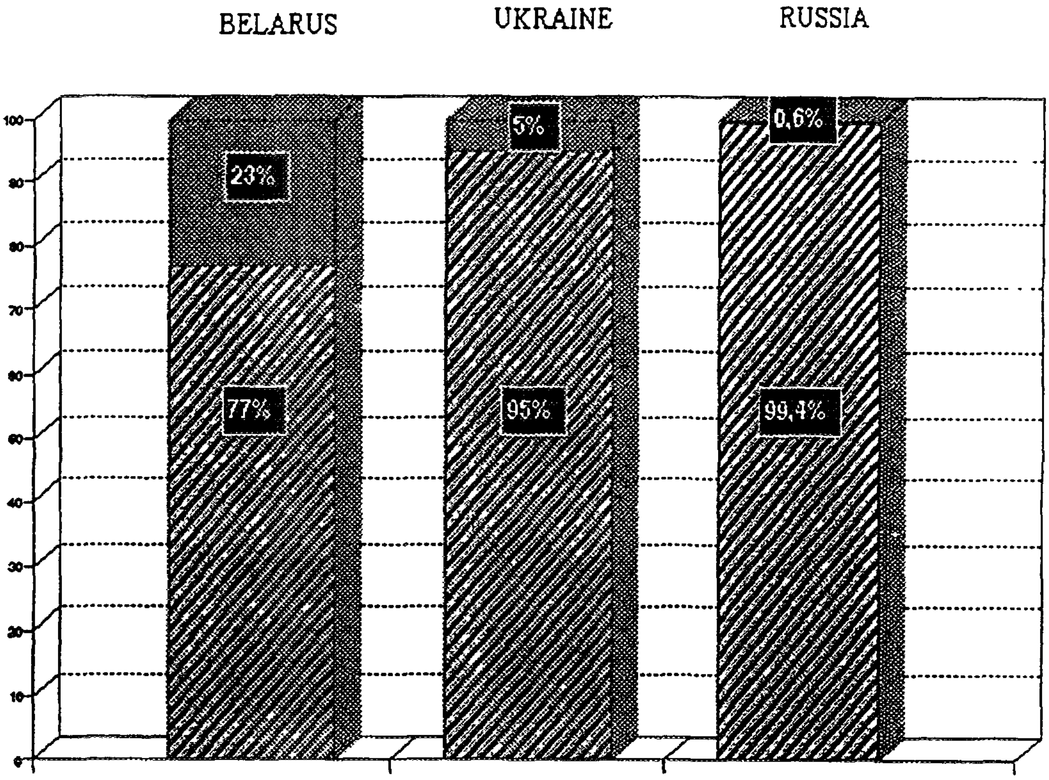


Fig 1 Areas in Belarus, the Ukraine and Russia with the density of caesium-137 pollution over 37 kBq/m^2 (the ratio to the total area of the countries territory)

By virtue of a primary direction of movement of air masses, contamination with radionuclides in the northern-western, northern and northern-eastern directions in the initial period after the accident, the significant increase of the exposition doze rate was registered practically on the whole territory of Belarus. In particular, the levels of a radioactive contamination by short-lived iodine-131 in many regions of the Republic were so great, that the resulting irradiation of millions of people is qualified by the experts as a period of "iodine impact " (fig. 2).

In April - May 1986, the highest levels of iodine-131 fall-out took place in the nearest 10-30 km zone in the Bragin, Khoiniki, Narovlya. Areas of the Gomel region, where the content of iodine-131 in the soils has amounted to 37000 kBq/sq.m. and more, and the exposition doze rate of the gamma-radiation has amounted to 25-100 mR/h.

In Chechersk, Kormyany, Buda-Koshelev, Dobrush Areas the levels of contamination reached 18500 kBq /sq.m.

The south-western regions, that is Elsk, Lelchitsy, Zhitkovichi, Petricovichi Areas of the Gomel Region and the Pinsk, Luninets, Stolin Areas of the Brest Region have been significantly contaminated.

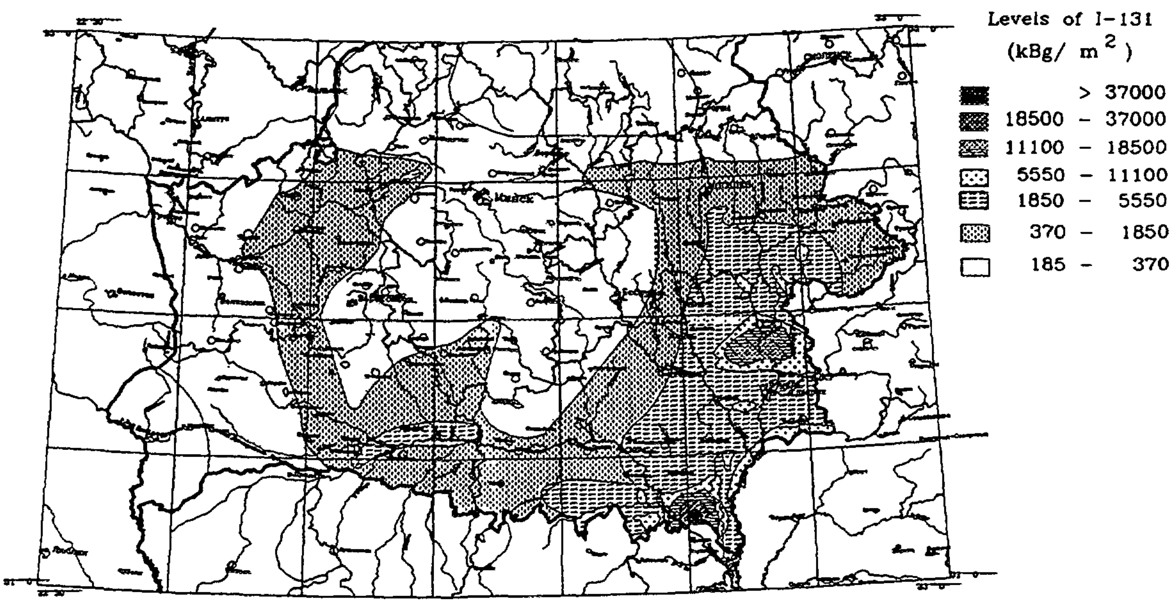


Fig.2 Radioactivity contamination of I-131 in soil on the territory of Belarus (10.05.1986)

The high levels contamination took place also on the north of the Gomel and the Mogilev Areas. For example, in a number of places the Vetka Area of the Gomel Region the content of iodine-131 in the soil was more than 20000 kBq/sq.m.. In the Mogilev Region the highest contamination by iodine-131 has been found out in the populated areas of the Cherikov and Krasnoбolye areas, where the level has amounted to 5550 - 11100 kBq / sq.m.

The high levels of contaminations the territory by iodine-131 have formed large dozes of irradiation, first of all, thyroid gland, has resulted in future in a significant increase of its pathology. As in January 1995, the number of the thyroid cancer cases for adolescents has accounted for 379 cases. For comparison only 4 cases have been registered in January,1986.

It evidences, that in comparison with Russia and Ukraine, the Republic of Belarus had appeared to be in more complex and heavy conditions on elimination of the consequences of the accident.

Important problem in the period following the accident was evaluation of radioactive contamination of the territory Belarus and creation of specially oriented monitoring (fig.3).

In Belarus 46,45 thouthands of square kilometers of the territory have been subjected to contamination with Cs-137, with its content in the soil equal to more than 37 kBq/sq.m. 27 cities and more than 3600 populated areas with the population 2,2 millions, that is more than1 / 5 of the population of Belarus are located on this territory.

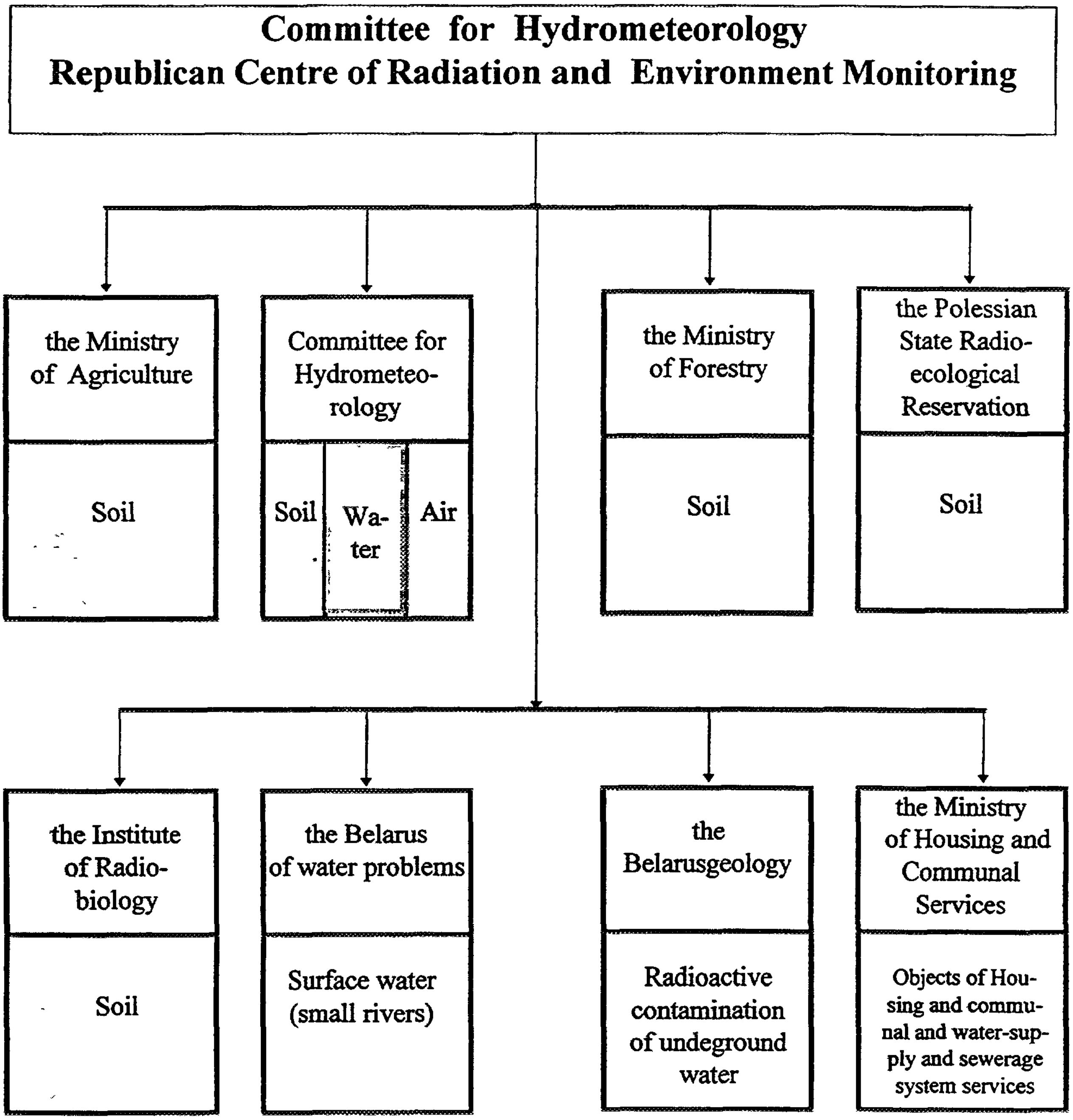


Fig. 3.

The Radiation Monitoring System on the territory of Belarus

2.METHODS

Each three year, accoding to the results of complex examination the maps of the content of caesium-137, strontium-90 and plutonium isotopes in the soil are issued. Taking into account the non-uniformity of the radioactive contamination and necessity of realization of protective measures on reduction of dose loads and increase of safe residence of the population on contaminated territories, the examination of 350 thousands of personal plots of land with issuing to the their owners the radiation passports.

As a result of accident at the ChNPP, the Gomel, Mogilev and Brest Regions have appeared to be the most contaminated.

There are cases, when within the same populated area, clean sites neighbor the highly contaminated places. The populated area Kolyban of the Bragin Area of the Gomel Region can be taken as an example, where the value of contamination with caesium-137 is in the range from 170 to 2400 kBq/sq.m. The maximum levels caesium-137 in the soil of the populated areas of the nearest zone have been found in the Bragin Areas - 2600 kBq/sq.m. and in the distant zone - at the distance 250 km, for instance, in the populated area Chudyany of the Chericov Area of the Mogilev Region. They accounted for 51000 kBq/sq.m. (fig.4).

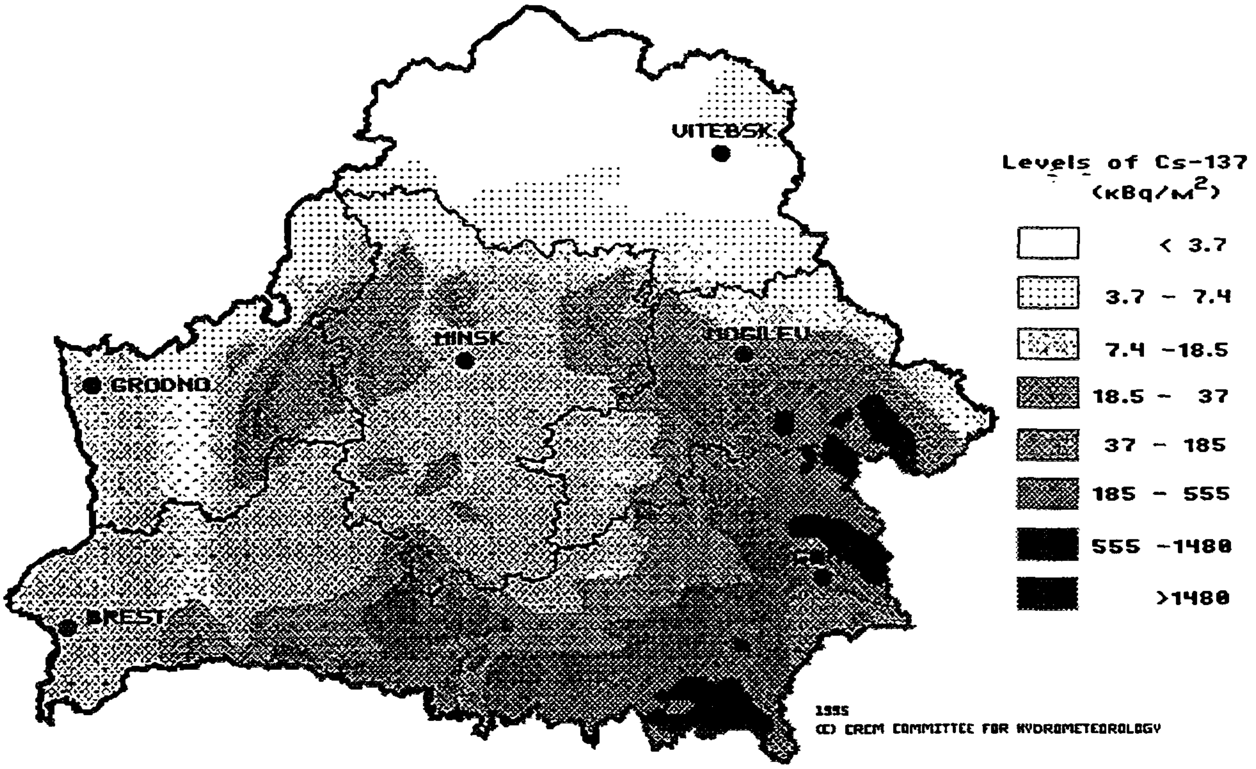


Fig.4 Radioactivity contamination of Cs-137 in soil of the territory of Belarus (01.01.1995)

In the Brest Region the south-east part has been subjected to contamination where in 6 regions the content of caesium-137 in the soil amount to 37 - 185 kBq /sq.m., and the maximum levels reach 400 kBq/sq.m. In the Minsk, Grodno and 4 populated areas of the Vitebsk Region the content of caesium-137 in the soil amounts to 37 kBq/sq.m. On the other territory of Belarus levels of contamination of the soil with caesium-137 are higher in comparison with the values before the accident and only the northern-western regions of the Vitebsk Region .They are comparable to global fall-outs. [1]

The contamination of the territory of the Republic with Sr-90 has more local character. The levels of contamination of the soil with Sr-90 more than 6,5 kBq/sq.m are found on the area 21,1 ths.sq.km., amounting 10 % of the total area of the Republic. The maximum levels Sr-90 in the soil in the populated areas of the nearest zone are found out within the 30-km zones of the ChNPP and 1800 kBq /sq.m. in the Khojniki area of the Gomel Region. The highest content of Sr-90 in the soil of a distant zone is found out at distance of 250 km - in Cherikov area of the Mogilev Region and 29 kBq/sq.m. including the northern part of the Gomel Region Vetka area - 137 kBq /sq.m. (fig. 5).

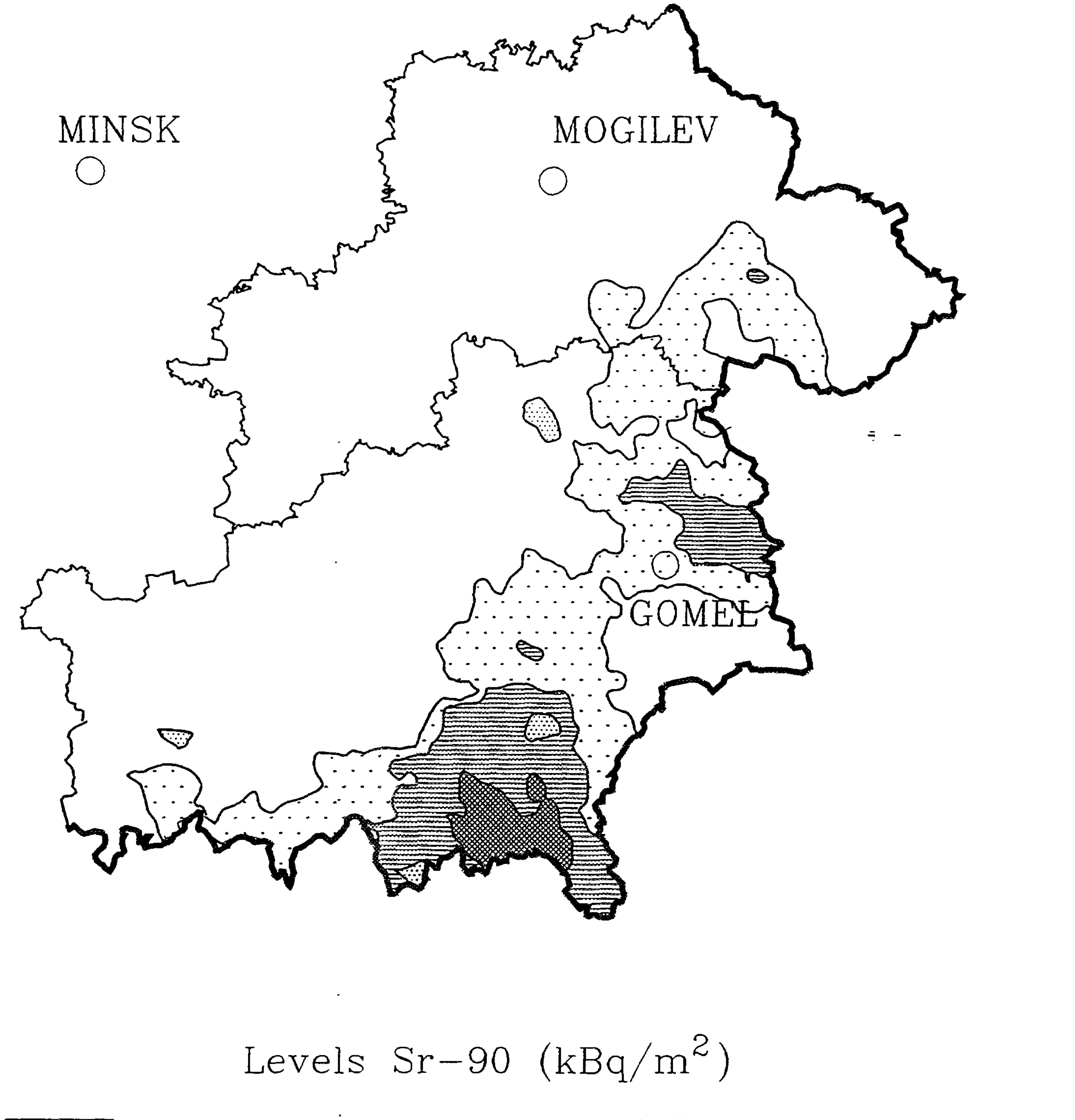


Fig.5 Radioactivity contamination of Sr-90 in soil on the territory Gomel and Mogilev regions of Belarus (01.01.1995)

The contamination of soil by the plutonium isotopes more than 0,37 kBq/sq.m. covers the area nearly 4,0 ths.sq.km., amounting to nearly 2 % of the area of the Republic. These territories are predominarthy in the Gomel Region and the Chechersk Area of the Mogilev Region.

Contamination of the soil by plutonium isotopes 0,37 up to 3,7 kBq/sq.m. is the highest in the Bragin, Narovlya, Khoiniki, Rechitsy and Dobrush, Loev Area of the Gomel Region. The contents of plutonium in the soil 3,7 êBq/sq.m is characteristic for 30-km zones of ChNPP. The highest levels of plutonium isotopes in the soil are observed in the Massany populated area of Khoiniki rea more than 111 kBq /sq.m (fig. 6).

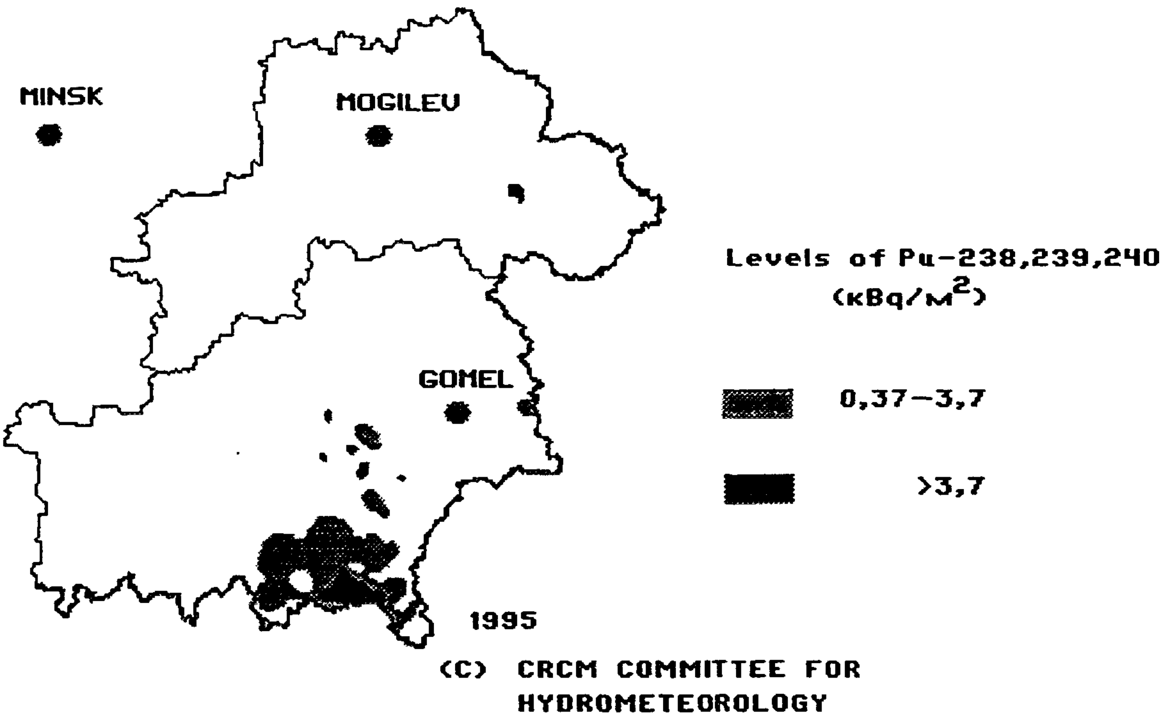


Fig 6

Radioactivity contamination of Pu-238,239,240 in soil on the territory of Gomel and Mogilev regions of Belarus (01.01.1995)

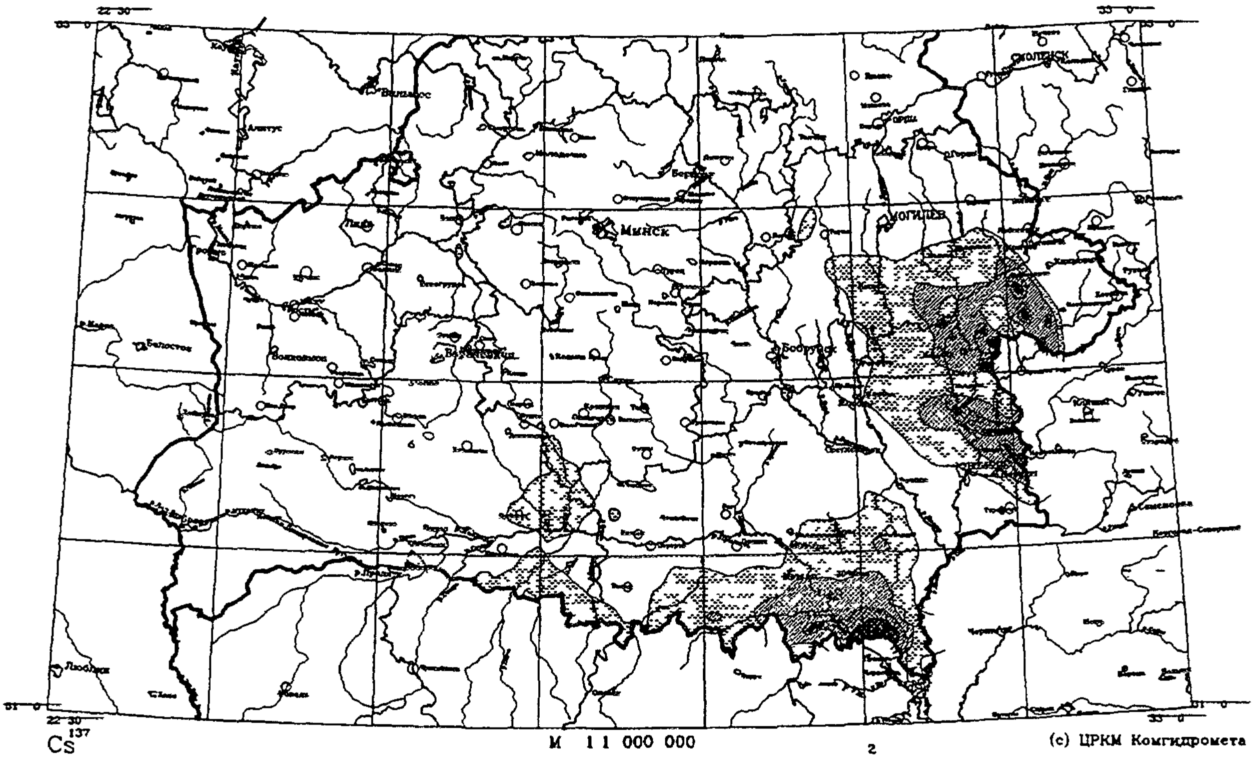
In accordance with the article 4 of the Low "About the Legal Region of the Territories, Subjected to Radioactive contamination after the accident at ChNPP " the territory of the Republic of Belarus is divided into zones depending on ràdioactive contamination of the soil by radionuclides and the value of the average annual effective doze equivalent.

3.RESULTS

At present the radiation situation of the territory of Belarus has stabilized however the results of monitoring show that in the soil and objects of environment the accumulation of ameritium-241 is observed and in course of , time its concentrations will increase.

Forecast of distribution on of caesium-137 on the territory of Belarus in 2016 y. shows that the contamination of more than 37 kBq/sq.m will be observes at the area more than 28,3 ths. km, that accounts 14% from the total territory of Belarus (fig. 7).

It connection with the above said it is necessary to emphasize the increased of role of the radiating control and monitoring of contaminated territories the result of which permit to observe changes to reveal additional sources of contamination, as well as to predict further development of radiation-ecological situation. This forecast should be the basis for formation of the policy of protective measures



Density of Cs-137 pollution of the territory (kBq/sq m)

37-185 | 185-555 | 555-1480 | over 1480

Fig 7 Map of radiation on situation on the Republic of the Belarus for 2016
Density of Cs-137 pollution of the territory (kBq/sq m)

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XA9745812

FORECASTING AND CONTROL OF THE MIGRATION OF RADIONUCLIDES UPPER SOIL LAYERS

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On the basis of natural observations and the laboratory researches of the radionuclides Cs-137 and Sr-90 migration in peat-swampy sites and soils the technique of the vertical radionuclide migration in upper soil layers forecast is developed. The computer technique takes into account the ions diffusion in pore solution, convection transfer ions with the moisture flow and the processes of radionuclide sorption by a soil-ground solid phase .

The behaviour radionuclides observation in the peat deposits, located 30 km zone off the Chernobyl, testify the slow migration of radionuclides into the upper layer. On the not influenced by anthropogenic effections peat soils, the depth of migration Cs-137 has not exceeded 160 mm, and Sr-90 - 200 mm. The main quantity (about 90 %) Cs-137 is in top 60 mm layer, and Sr-90 - in 90 mm layer. At the same time on the subjected to agricultural processing peat deposits radionuclides are in regular intervals distributed on 200 mm layer. The mathematical model of the radionuclides transfer characteristic has been determined. The electrolyte influence on the sorption and diffusion processes of radionuclides Cs-137 and Sr-90 in typical natural disperse systems (the main soil components of Belarus) have been investigated. The most significant influence to factors of Cs-137 and Sr-90 distribution and diffusion have been established. First of all, it is an availability of the stable elements Cs and Sr in the pore solution to increase the effective diffusion factor till two decimal orders. It has been shown, that Cs-137 radionuclides in the technogenic pollution of the Chernobyl NPS peat are basically in the exchange form and during 8-12 months can pass to water soluble condition by the effect of salts chloride alkali and alkali-ground metals . The heaviest efficiency has chloride stable caesium.

On the basis of the developed computer program and the experimentally determined transfer haracteristics the prognosis valuation of migration Cs-137 in the peat deposit "Pogonyanskoe " (21 km from the Chernobyl NPS) has been made.

Известно, что подавляющее количество радионуклидов, выброшенных в природную среду в результате аварии на ЧАЭС, в настоящее время сосредоточено в верхних слоях почво-грунтов. Радионуклиды в основном находятся в связанном состоянии за счет сорбции их твердой фазой почво-грунтов, и только незначительная их часть находится в водорастворимом состоянии. При этом различные формы радионуклидов в почво-грунтах находятся в условиях динамического равновесия между собой. Под воздействием различных факторов, естественных и антропогенных, часть радионуклидов может попадать в грунтовые воды, накапливаться растениями и таким образом распространяться по всей экологической цепи. Для минимизации отрицательных воздействий этой аварии на здоровье людей и окружающую среду необходимо иметь достоверные методики долговременного прогноза миграции радионуклидов в природных средах, учитывающие различные естественные и антропогенные факторы, а также знать основные принципы и способы направленного воздействия на процессы миграции радионуклидов.

В силу ряда особенностей естественные торфяно-болотные ландшафты являются удобными объектами для наблюдения за миграцией радионуклидов и динамикой радиоэкологической обстановки в местах с различными уровнями загрязнения. На таких торфяных месторождениях не проводится хозяйственная деятельность, они редко посещаются человеком,т.е. эти объекты не подвергаются антропогенной нагрузке и процесс миграции радионуклидов протекает в естественных условиях.

Загрязненные торфяно-болотные ландшафты на территории Беларуси различаются по плотности и характеру загрязнения радиоактивными веществами. Эти различия обусловлены тем, что отдельные участки подвергались загрязнению в разные сроки, а, следовательно, при различных погодных условиях, различных направлениях и силе ветра Кроме того, внутри загрязненных зон образовались отдельные локальные участки, отличающиеся по плотности и характеру загрязнения в связи со вторичным перераспределением радиоактивного вещества под воздействием геофизических и геохимических процессов, протекавших в меняющихся погодных условиях и под влиянием отличающихся водных режимов, почвенных характеристик и геоморфологических условий. В связи с этим, места для размещения полигонов для проведения полевых исследований подбирались на торфяных месторождениях, расположенных вблизи реперных участков, которые были определены координационным советом по проведению научных исследований по Чернобыльской тематике.

На десятом году после аварии на ЧАЭС характер радиоактивного загрязнения почво-грунтов по гамма-излучению определяет в основном Cs -137. Процесс миграции Cs-137 наиболее наглядно можно продемонстрировать на примере четырех объектов, расположенных в зоне отселения. По геоморфологическим условиям объект 1 торфяное месторождение "Погонянское" относится к группе месторождений крупных равнин Полесья; объекты 2 - "Савичи" и 3 - "пойма реки Брагинка" относятся к группе пойменных месторождений; объект 4 -"Новоселки" представляет собой небольшую торфяную залежь площадью не более 10 га. Объекты 1 и 2 после аварии на ЧАЭС в сельскохозяйственном производстве не использовались. На объектах 3 и 4 выращивают клевер и многолетние травы; почва периодически (1 раз в 2 года) подвергается обработке дисковыми культиваторами.

Общая картина распределения цезия-137 на десятом году в верхнем слое указанных объектов приведена на рис.1. Из приведенных данных видно, что глубина верхнего слоя торфяной залежи, содержащего 90% цезия-137 от общего его количества. на объекте 1 не превышает 50 мм и 70 мм на объекте 2. В тоже время, на объектах 3 и 4, включенных в сельскохозяйственное производство, такое же количество радионуклидов содержится в слое 160 мм. Многолетними натурными наблюдениями установлено, что на интенсивность миграционных процессов оказывают влияние кислотность и степень обводненности торфяной залежи.

Чем выше уровень грунтовых вод и кислотность торфяной залежи, тем глубже проникают в нее радионуклиды. С этих позиций можно объяснить большую глубину проникновения Cs-137 на объекте 2 по сравнению с объектом 1, так как уровень грунтовых вод на этих объектах соответственно составлял 0,3м и 0,6 м. Что касается Sr-90, то глубина его проникновения на торфяных месторождениях, не подвергающихся антропогенному воздействию, в 1,5 раза выше, чем Cs -137.

Лабораторные исследования процессов миграции радионуклидов в почво-грунтах велись с целью уточнения математических моделей этих процессов, определения характеристик переноса, входящих в математические модели, и изучения влияния электролитов на процессы сорбции и диффузии Cs-137 и Sr-90 в типичных природных дисперсных системах, являющихся основными компонентами почво-грунтов Беларуси.

На основании анализа литературных источников [1,2] и собственных экспериментальных исследований мы пришли к выводу, что наиболее полно физику процессов переноса отражает система уравнений, учитывающая кинетику фазового перехода радионуклида в системе твердая фаза-раствор. При этом полагается, что

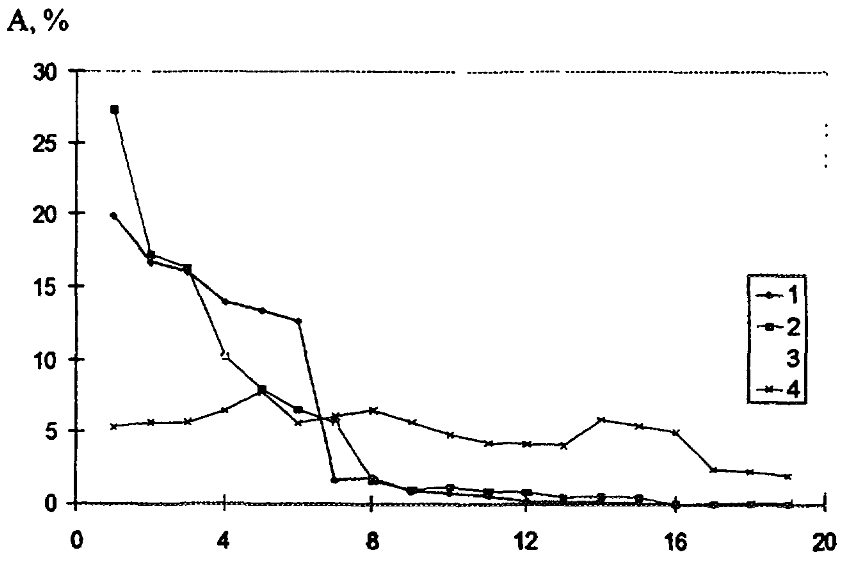

Рис.1. Процентное содержание Cs-137 по глубине пахотного горизонта (номер кривой соответствует номеру объекта).

процессы переноса осуществляются в основном в поровом растворе по механизму молекулярной диффузии, практически не отличающемся от диффузии в объемном водном растворе. Соотношение радионуклидов, находящихся в поровом растворе и связанных твердой фазой, определяется коэффициентами распределения и массообмена. Система уравнений массообмена в этом случае будет иметь вид

$$\frac{\partial C1}{\partial \tau} = K_i D_0 \frac{\partial^2 C1}{\partial x^2} - V\frac{\partial C1}{\partial \tau} - \frac{\alpha}{W}\left(\frac{1}{K_d}C2 - C1\right), \quad (1) \qquad \frac{\partial C2}{\partial \tau} = -\alpha\left(\frac{1}{K_d}C2 - C1\right), \quad (2)$$

где C1 - концентрация радионуклида в поровом растворе; C2 - концентрация радионуклида в твердой фазе системы; D_o- коэффициент молекулярной диффузии радионуклида; V - линейная скорость конвективного переноса влаги; K_i- коэффициент извилистости диффузионного пути; K_d- коэффициент распределения, характеризующий соотношение радионуклида, связанного твердой фазой материала и находящегося в поровом растворе; α - коэффициент массообмена радионуклида в системе твердая фаза материала - поровый раствор; W - влагосодержание материала.

При достаточно больших коэффициентах массообмена и малых скоростях конвективного переноса влаги система уравнений (1), (2) переходит в уравнение (3)

$$\frac{\partial C1}{\partial \tau} = \frac{D_0 K_i}{\frac{K_d}{W}+1}\frac{\partial^2 C1}{\partial X^2} - \frac{V}{\frac{K_d}{W}+1}\frac{\partial C1}{\partial X}, \quad (3) \qquad D_{эф} = \frac{D_0 K_i}{1+\frac{K_d}{W}} \quad (4)$$

Комплекс параметров, стоящих перед второй производной концентрации по координате, соответствует эффективному коэффициенту диффузии радионуклида и может быть выражен с помощью формулы (4).

Расчет процессов диффузионного и конвективного переноса радионуклидов в верхних слоях почво-грунтов для большинства задач теоретического и практического направления из-за нелинейности уравнений переноса может производиться только численными методами. По этой же причине определение параметров массообмена радионуклидов, входящих в математические модели в основном также производится численными методами. Для этих целей на основании системы уравнений (1) и (2) была получена аналогичная система в конечно-разностной форме и разработана прикладная программа для ЭВМ. Эта программа позволяет рассчитывать как прямые задачи диффузионного и конвективного переноса радионуклидов для прогноза их миграции, так и обратные задачи, в которых на основании пространственно-временных распределений радионуклидов в образце определяются параметры массопереноса этих радионуклидов.

Из анализа приведенных математических моделей миграции радионуклидов следует, что основными параметрами, от которых зависит диффузионная и конвективная подвижность радионуклидов в почво-грунтах, являются: коэффициент молекулярной диффузии, коэффициент распределения, коэффициент извилистости и коэффициент массообмена . Вместо произведения параметров $D_o \cdot K_i$ в уравнениях (1) и (3) можно использовать параметр $D_п$, характеризующий коэффициент диффузии радионуклидов в поровом растворе почво-грунтов с учетом структуры порового пространства. При достаточно больших коэффициентах массообмена ($\alpha > 10^{-6}$ c^{-1}) для математического описания процессов переноса радионуклидов с помощью уравнения (3) достаточно двух параметров- коэффициента эффективной диффузии и коэффициента распределения .

Достоверность прогноза миграции радионуклидов в почво-грунтах будет определяться прежде всего тем, насколько точно и полно выявлены зависимости всех параметров массообмена радионуклидов от влагосодержания почво-грунтов, концентрации минеральных водорастворимых соединений и других физико-химических факторов.

Методами математического моделирования и экспериментальными исследованиями было установлено, что при малой скорости перехода радионуклидов раствор-твердая фаза в системе из двух контактирующих пластин, имеющих различные начальные концентрации радионуклидов, наблюдается существенное различие в коэффициентах распределения в донорной и акцепторной областях. Это различие изменяется с течением времени по закону, близкому к экспоненциальному, и зависит, в основном, от коэффициента массообмена . На основании этого факта была разработана комплексная методика определения $D_п$,α и K_d. Для этого два образца в форме пластиин с различной исходной концентрацией радионуклидов приводятся в контакт и выдерживаются в течение 2-4 месяцев. Образец с большей концентрацией радионуклидов в дальнейшем будем называть донорным, а с меньшей- акцепторным.После разъединения донорной и акцепторной частей с исследуемым материалом незамедлительно производится отжатие порового раствора в каждой из этих частей и рассчитываются коэффициенты распределения . Далее на ЭВМ, по специально разработанной программе, производится обработка результатов эксперимента. В основу алгоритма этой программы положен расчет распределения концентрации радионуклидов в системе двух пластин при диффузии этих радионуклидов под воздействием градиента концентрации методом конечных разностей и нахождения методом последовательных приближений коэффициента массообмена и коэффициента диффузии $D_п$ при условии соответствия расчетных и экспериментальных значений относительной среднеинтегральной концентрации и отношения коэффициентов распределения в донорной и акцепторной кассетах.

Для определения характеристик массообмена радионуклидов в типичных природных дисперсных системах использованы образцы низинного осокового торфа с техногенным загрязнением в результате аварии на ЧАЭС из месторождения "Погонянское", находящегося в тридцатикилометровой зоне. Более детальные исследования проведены на образцах низинного осокового торфа степени разложения R = 30% и зольности A = 12%, каолина и кварцевого песка с размером фракций менее 0.25 мм. В эти системы были внесении растворы хлоридов Cs-137 и Sr-90 с расчетом активности $0.5 \cdot 10^6$ Бк/кг влажного материала.

После выдержки образцов во влагоизолированном состоянии в течение 2 месяцев в образцы вносились растворы электролитов KCl, KOH, $CaCl_2$, а также растворы соответствующих стабильных элементов CsCl и $SrCl_2$. Концентрации электролитов в поровых растворах приготовленных образцов изменялась от 0.001 до 0.1 г-экв/л. Образцы выдерживались снова в стационарных условиях в течение 2 месяцев, а затем в них определялись коэффициенты распределения и диффузии.

В табл.I представлены экспериментальные данные по коэффициентам распределения и диффузии Cs-137 и Sr-90 в исследованных системах при некоторых концентрациях электролитов в поровом растворе.

Анализ данных показывает, что наличие в поровом растворе хлоридов стабильного Cs-137 уменьшает коэффициент распределения и увеличивает коэффициент диффузии более, чем на 2 десятичных порядка. Эффективность влияния KCl на коэффициенты распределения и диффузии Cs-137 гораздо меньше, чем хлорида стабильного Cs. Наличие в поровом растворе KOH и $CaCl_2$ не оказывает существенного влияния на

Таблица I

Коэффициенты распределения и диффузии радионуклидов в природных дисперсных системах при наличии в поровом растворе электролитов

		Cs-137			Sr-90		
Образец	Электролит, г-экв/л	$K_{d\,дон}$	$K_{d\,акц}$	$D_{эф}$	$K_{d\,дон}$	$K_{d\,акц}$	$D_{эф}$
торф низинный W=2.5 кг/кг	исходный	2043	244	$0.9\cdot10^{-13}$	180	180	$3.2\cdot10^{-12}$
	$CsCl/SrCl_2$, 0.1*	13	5	$1.8\cdot10^{-11}$	16	17	$1.7\cdot10^{-11}$
	KCl, 0.1	160	35	$7.0\cdot10^{-13}$	33	10	$6.0\cdot10^{-12}$
	$CaCl_2$, 0.1	725	116	$1.0\cdot10^{-13}$	29	27	$4.0\cdot10^{-12}$
	KOH, 0.05	805	63	$1.1\cdot10^{-13}$	227	227	$3.0\cdot10^{-13}$
	HCl, 0.2	85	80	$7.8\cdot10^{-12}$	16	10	$1.0\cdot10^{-11}$
каолин W=0.5кг/кг	исходный	312	9	$3.2\cdot10^{-14}$	103	81	$7.0\cdot10^{-12}$
	$CsCl/SrCl_2$,0.1*	17	2	$1.2\cdot10^{-12}$	8.3	7	$2.2\cdot10^{-11}$
	KCl,0.1	212	2.4	$9.9\cdot10^{-14}$	2	11	$1.5\cdot10^{-11}$
	$CaCl_2$, 0.1	272	18	$4.4\cdot10^{-14}$	19	16	$1.4\cdot10^{-11}$
	KOH, 0.05	224	6.5	$2.8\cdot10^{-14}$	140	75	$4.7\cdot10^{-12}$
	HCl, 0.2	120	25	$1.6\cdot10^{-13}$	4.3	2.8	$2.5\cdot10^{-11}$
песок кварцевый W=0.2 кг/кг	исходный	49	16	$1.8\cdot10^{-13}$	1.4	0.3	$1.5\cdot10^{-11}$
	$CsCl/SrCl_2$,0.1*	3.5	0.1	$3.2\cdot10^{-13}$	0.04	0.01	$1.1\cdot10^{-10}$
	KCl,0.1	6.4	5	$2.7\cdot10^{-12}$	0.15	0.07	$4.7\cdot10^{-11}$
	$CaCl_2$, 0.1	32	9	$1.6\cdot10^{-13}$	0.1	0.1	$1.0\cdot10^{-10}$
	KOH, 0.05	22	2	$5.2\cdot10^{-13}$	6	1	$1.9\cdot10^{-12}$
	HCl, 0.2	3.2	1.7	$5.6\cdot10^{-13}$	0.02	0.02	$1.1\cdot10^{-10}$

* Примечание. В образцы с Cs-137 вносился CsCl, со Sr -90 - $SrCl_2$

коэффициенты распределения и диффузии Cs-137. При внесении в образцы соляной кислоты в количестве, соответствующем ее концентрации в поровом растворе 0.2 г-экв/л, наблюдается уменьшение коэффициента распределения и увеличение коэффициента диффузии Cs-137 почти на два порядка.

Следует обратить внимание, что коэффициенты распределения Cs-137. определенные в донорных и акцепторных образцах, для торфа, не модифицированного добавками электролитов, отличаются в 8 раз. Это говорит о том, что процессы установления фазового равновесия раствор-твердая фаза для Cs-137 протекают медленно, в течение нескольких месяцев. В установившемся состоянии коэффициент распределения Cs-137 в образцах торфа, в которые он был внесен в виде раствора хлорида, весьма близок к аналогичному коэффициенту в образцах техногенного загрязнения из торфяного месторождения "Погонянское" в Чернобыльской зоне.

В низинный торф с техногенным загрязнением 10^5 Бк/кг по Cs-137 внесен раствор хлорида Cs-137 с удельной активностью 10^6 Бк/кг. В этот же торф внесен раствор хлорида стабильного цезия в таком количестве, чтобы концентрация порового раствора по стабильному Cs составляла 0.2 г-экв/л. Определяя периодически коэффициент распределения Cs-137 в этих образцах, было установлено, что через 1 месяц коэффициент распределения Cs-137 в первом образце достиг значения 2000, т.е. внесенный Cs-137 стал связан в такой же степени как Cs-137 техногенного загрязнения. Во втором образце, наоборот, на прстяжении длительного времени наблюдалось постепенное снижение коэффициента распределения Cs-137. Так, коэффициент распределения через 1 месяц равнялся 40, через 4 месяца - 13, через 10 месяцев - 1.2, т.е. Cs-137 вытеснялся постепенно стабильным цезием из твердой фазы торфа в поровый раствор. Это позволяет заключить, что основное количество Cs-137 техногенного загрязнения в торфяных почвах находится в обменной форме, но имеет сравнительно малую величину коэффициента массообмена. Это значит, что с помощью воздействия электролитов в торфах техногенного загрязнения, Cs-137 можно перевести в водорастворимое состояние в течение определенного промежутка времени.

Коэффициенты распределения Sr-90 в исходном торфе без добавок электролитов на порядок ниже, чем для Cs-137, а коэффициенты диффузии, соответственно, выше. Установление фазового равновесия Sr-90 раствор-твердая фаза происходит гораздо быстрее, чем Cs-137. Наиболее эффективное воздействие на увеличение подвижности Sr-90 оказывают добавки CsCl, KCl и HCl, при их концентрации в поровом растворе 0,1-0,2 г-экв/л.

Анализ влияния электролитов на коэффициенты распределения и диффузии радионуклидов Cs-137 и Sr-90 в каолине (табл. I) показывает, что, также как и для торфа, наибольшее влияние на изменение этих коэффициентов оказывает наличие в поровом растворе хлорида стабильного Cs при концентрации 0.1 г-экв/л. Добавки KOH и $CaCl_2$ не приводят к существенному изменению коэффициентов распределения и диффузии Cs-137 в каолине.

Кварцевый песок (табл.I) в достаточной степени адсорбирует Cs-137 и очень мало адсорбирует Sr-90. Вследствие этого, эффективные коэффициенты диффузии Cs-137 в кварцевом песке на два десятичных порядка ниже, чем Sr-90. Наличие в поровом растворе HCl, KCl и соответствующих хлоридов стабильных Cs и Sr уменьшает коэффициенты диффузии в кварцевом песке Cs-137 и Sr-90. Добавки KOH, напротив , увеличивают коэффициенты распределения и снижают эффективные коэффициенты диффузии в кварцевом песке указанных радионуклидов. Внесение в поровый раствор кварцевого песка $CaCl_2$ по разному влияет на параметры адсорбции и переноса Cs-137 и Sr-90; если для Cs-137 это влияние не существенно, то для Sr-90 также, как и при внесении KCl или $SrCl_2$, характерно снижение адсорбции и увеличение эффективного коэффициента диффузии .

Следует отметить, что эффективные коэффициенты диффузии Cs-137 во всех исследованных системах в гораздо большей степени понижены по сравнению со Sr-90, что может быть обусловлено соответствующим различием коэффициентов распределения. Более значительное понижение эффективного коэффициента диффузии для Cs-137 можно объяснить меньшим значением коэффициента массообмена, т.е. большей длительностью процесса фазового перехода раствор-твердая фаза Cs-137 в исследованных системах по сравнению со Sr-90. Учитывая этот фактор, с помощью ЭВМ были обработаны результаты опытов по диффузии Cs-137 с учетом кинетики фазового перехода в системе раствор-твердая фаза для торфяных и глинистых систем. Данные этих исследований представлены в табл. II. В этой же таблице представлены данные по характеристикам переноса и обмена Cs-137 в низинном торфе из месторождения "Погонянское" с техногенным загрязнением в результате аварии на ЧАЭС.

Анализ данных показал, что коэффициенты диффузии и распределения Cs-137 техногенного загрязнения практически не отличаются от аналогичных характеристик для Cs-137, лабораторно внесенного в виде хлоридов. В то же время было установлено, что коэффициенты массообмена для техногенного и лабораторного радиоактивного загрязнения имеют отличие, что можно объяснить спецификой техногенного загрязнения торфа радионуклидами (наличие "горячих" частиц) и более глубоким внедрением Cs-137 в матрицу торфа с течением времени и включение этого элемента в состав комплексных системах. С помощью разработанной программы и полученных параметров масообмена были выполнены расчеты процессов переноса Cs-137 в торфяной залежи месторождения "Погонянское". На первом этапе для расчета были использованы эффективные значения коэффициента диффузии и коэффициента распределения, полученные лабораторными исследованиями, (Dэф=1 10^{-13} $м^2/с$ и Kd= 2000) при условии, что фазовое равновесие Cs-137 в системе поровый раствор-твердая фаза устанавливается достаточно быстро. Расчет конвективного переноса проведен при условии изменения линейной скорости переноса влаги по периодическому закону с периодом и амплитудой, соответствующими среднемесячной норме осадков и интенсивности испарения влаги в регионе месторождения "Погонянское". Начальное распределение радиоактивного загрязнения было принято равномерным в слое толщиной 3 см с удельной активностью 10^5 Бк/кг.

Выполненные расчеты (рис.2) показали, что за 8 лет радиоактивное загрязнение распространится до 10 см. Суммарная активность поверхностного слоя толщиной 3 см за это время уменьшится на 45%.

Далее, были выполнены расчеты миграции Cs-137 в залежи с учетом скорости массообмена поровый раствор-твердая фаза. В расчетах приняты значения коэффициента массообмена 10^{-8} $с^{-1}$ и коэффициента диффузии Cs-137 в поровой влаге $8 \cdot 10^{-10}$ $м^2/с$.

Распределение Cs-137 в торфяной залежи через 20 лет с указанными параметрами переноса и параметрами линейной скорости влаги, принятыми ранее, представлены на рис.2 (кривая 4). Из приведенных данных видно, что учет скорости массообмена радионуклида в систееме поровый раствор-твердая фаза изменяет характер распределения Cs-137; максимум концентрации сдвигается ближе к поверхности, уменьшается вынос радионуклида из поверхностного слоя и в то же время увеличивается протяженность зоны радиоактивного загрязнения.

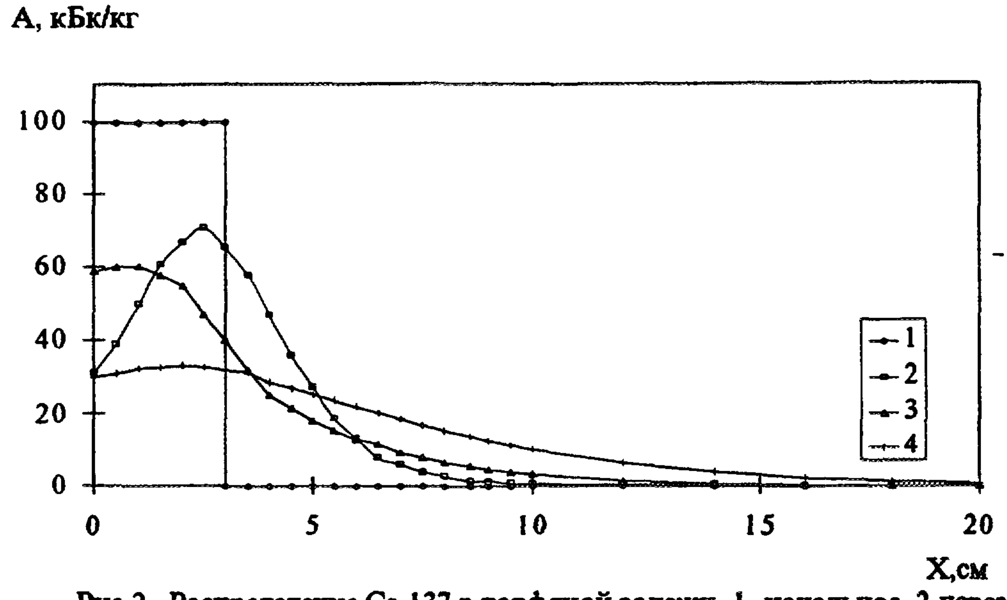

Рис.2. Распределение Cs-137 в торфяной залежи. 1- начальное, 2-через 8 лет ($D_{эф}=10^{-13}$ $м^2/с$), 3-через 8лет, 4- через 20 лет ($D_{пр}=8 \cdot 10^{-10}$ $м^2/с$, $\alpha=10^{-8}$ $с^{-1}$).

Таким образом, расчет процесса переноса Cs-137 необходимо производить с учетом кинетики перехода этого элемента из твердой фазы в водорастворимое состояние. Выполненные расчеты носят оценочный характер. Для более точного расчета процессов перераспределения радионуклидов в природных дисперсных системах необходимо параллельно вести расчет динамики температурных и влажностных полей в этих системах.

В заключение следует отметить, что в верхних слоях почво-грунтов: не подвергающихся активной деятельности человека: достаточно долгое время радионуклиды будут находиться в верхнем слое: не превышающем 20 см, Однако, внесение в почвы различных минеральных соединений может существенно изменить интенсивность миграции и соответственно глубину распространения радионуклидов, Это необходимо учитывать при вовлечении территорий , подвергшихся радиоактивному

Таблица II.

Параметры массообмена Cs с учетом кинетики фазового перехода раствор- твердая фаза.

Материал	W, кг/кг	A,Бк/кг	K_d	$D_{пр}$, $м^2/с$	α, c^{-1}
Каолин	0.5	$0.5 \cdot 10^6$	312	$7.79 \cdot 10^{-10}$	$1.55 \cdot 10^{-8}$
Бентонит	1.25	$0.5 \cdot 10^6$	406	$9.94 \cdot 10^{-10}$	$5.69 \cdot 10^{-8}$
Кварцевый песок	0.2	$0.2 \cdot 10^6$	49	$1.43 \cdot 10^{-10}$	$8.54 \cdot 10^{-8}$
Торф низинный	2.5	$0.5 \cdot 10^6$	2043	$6.56 \cdot 10^{-10}$	$2.93 \cdot 10^{-8}$
Торф из м/р “Погонянское”	2.5	$4 \cdot 10^4$	2000	$8 \cdot 10^{-10}$	$1.0 \cdot 10^{-8}$

соединений. Однако, указанные факторы не исключают возможности математического моделирования процессов переноса Cs-137 в природных дисперсных системах с техногенным загрязнением с помощью системы уравнений (1) и (2), необходимо только правильно определить характеристики переноса и массообмена Cs-137 в указанных загрязнению в результате аварии на ЧАЭС в сельскохозяйственное производство, а также использовать для направленного воздействия на процессы миграции радионуклидов с целью удаления их из активного почвенного слоя.

[1] ПРОХОРОВ В.М. Миграция радиоактивных загрязнений в почвах, Энергоатомиздат, Москва (1981), 97с.

[2] АЛЕКСАХИН Р.М., ВАСИЛЬЕВ А.Д. и др. Сельскохозяйственная радиоэкология, Экология, Москва (1991), 397с.

RADIOECOLOGICAL ASPECTS OF THE REHABILITATION OF LAND CONTAMINATED BY RADIONUCLIDES FOLLOWING THE CHERNOBYL ACCIDENT

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РАДИОЭКОЛОГИЧЕСКИЕ АСПЕКТЫ РЕАБИЛИТАЦИИ ТЕРРИТОРИЙ, ЗАГРЯЗНЕННЫХ РАДИОНУКЛИДАМИ ПОСЛЕ АВАРИИ НА ЧАЭС

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One of the important approaches while remediation of the areas contaminated with radionuclides is the radioecological prediction of individual doses and the estimation of potential contribution of produced food products into the collective dose. On the example of the Chechersk region in the Gomel area there have been selected areas where in 1995 individual doses exceeded the level of intervention of 1 mSv/y, the contribution of internal irradiation into the total dose has been determined and the means of its reduction have been proposed. The radical improvement of pastures for grazing of private animals is the drastic measure of the internal irradiation dose reduction formed by milk. It is shown that since the moment of using herbages of a cultivated pasture during five subsequent years the diverted individual dose from milk can be 0.98 mSv while the average contamination level of 405 kBq/ m². There were estimated thecurrents of radionuclides with foodstuffs derived from various ecosystems and the variants of applying of countermeasures to reduce the collective dose were considered.

1.ВВЕДЕНИЕ

Сложность проблемы реабилитации загрязненых территорий определяется множеством факторов социально-экономического, демографического, психологического, радиационно-гигиенического и радиоэкологического характера.

Реабилитация загрязненных территорий не должна ограничиваться отдельными населенными пунктами, так как структура государственных сельскохозяйственных предприятий представлена общим комплексом производственных, социально-экономических и организационных объектов с управляющим центром. Оптимальная территория для разработки системы мер по реабилитации - территория административного сельскохозяйственного района.

Возможность реабилитации территории в первую очередь зависит от сложившейся к настоящему времени радиоэкологической обстановки, формирующей дозовые нагрузки.

2. ПРИНЦИПЫ РЕАБИЛИТАЦИИ ЗАГРЯЗНЕННЫХ ТЕРРИТОРИЙ

Основные принципы общей методологии реабилитации загрязненных территорий следующие:

1. Принцип комплексности, на основе которого рассматриваются все стороны жизни и деятельности людей, проживающих на территории загрязненного района.

2. Принцип радиоэкологического прогнозирования индивидуальных и коллективных доз на реабилитируемой территории.
3. Принцип последовательности планирования защитных и экономических мер на основе их значимости или приоритетности.
4. Принцип взаимосвязи социально-экономической и радиоэкологической ситуаций, повлиявший на общее состояние загрязненной территории и определяющий возможности государственной финансовой поддержки процесса реабилитации.
5. Принципиальная неполнота данных, позволяющая принимать решение о реабилитационных мерах на основе установленных закономерностей.
6. Принципиальная неоднозначность результатов оценки прогнозирования ситуации при консервативном и радикальном подходах.
7. Противоречивость сложившейся ситуации с правовыми нормами.

3. РАДИОЭКОЛОГИЧЕСКОЕ ПРОГНОЗИРОВАНИЕ ИНДИВИДУАЛЬНЫХ ДОЗ

Основной критерий возможности реабилитации загрязненной территории - прогноз достижения индивидуальных дозовых нагрузок, не превышающих уровня вмешательства 1 mЗв/год.

На примере Чечерского района Гомельской области проанализировано распределение населенных пунктов по средним индивидуальным дозам 1994 года и показано, что из 113 населенных пунктов в 90 из них индивидуальная доза не превышает 1 mЗв в год, в 13 - достижение дозового уровня 1 mЗв возможно до 2000 года и в 10 населенных пунктах - после 2000 года (табл.I).

Таблица I

Прогноз времени достижения уровня индивидуальной дозы 1 mЗв/год в населенных пунктах Чечерского района

NN п/п	Населенный пункт	Доза mЗв/год		Год выхода на 1 mЗв/год
		суммарная	внутренняя	
1.	Чечерск	1.2	0.8	1996
2.	Новозахарполье	1.1	0.6	1996
3.	Красный Берег	1.1	0.7	1996
4.	Сычевка Рудницкая	1.2	0.6	1996
5.	Калинино	1.1	0.6	1996
6.	Черн.Малыничи	1.1	0.5	1996
7.	Сидоровичи	1.1	0.9	1996
8.	Юный	1.2	0.7	1997
9.	Ипполитовка	1.2	0.5	1998
10.	Будище	1.3	0.5	2000
11.	Коробка	1.4	0.8	2001
12.	Ивановка	1.5	0.9	2002
13.	Науховичи	1.4	0.3	2003
14.	Ивановка	1.6	0.8	2003
15.	Красный Дворец	2.1	1.6	2004
16.	Залавье	1.7	0.8	2004
17.	Холочье	1.5	0.4	2004
18.	Медвежье	1.6	0.5	2005
19.	Алексеевка	1.5	0.2	2005
20.	Канавы	1.6	0.4	2006
21.	Р. Дудическая	2.1	0.8	2010
22.	Дудичи	1.8	0.3	2012
23.	Лук. Поплавы	1.8	0.1	2014

В населенных пунктах, где доза внешнего облучения достигает 50% и более от суммарной дозы , т.е. является ведущей, достижение уровня невмешательства 1 mЗв возможно только после 2000 года. Следует отметить, что представленные результаты расчетов достижения уровня в 1 mЗв/год выполнены при консервативном подходе без учета влияния контрмер.

Так как молоко формирует до 80% среднегодовой индивидуальной дозы от внутреннего облучения населения, проживающего на загрязненных территориях проведена сравнительная оценка доз внутреннего облучения от молока после проведения коренного улучшения лугов (табл.II).

Таблица II

Среднегодовые эффективные дозы внутреннего облучения, обусловленные молочной компонентой, при средней плотности загрязнения пастбищ Чечерского района 405 кБк/м² (mЗв/год).

Годы	Выпас коров на естественном лугу	Выпас коров на лугу после коренного улучшения
1989*	0.66	0.66
1990	0.53	0.53
1991**	0.44	0.33
1992	0.38	0.20
1993	0.36	0.14
1994	0.33	0.10
1995	0.31	0.08
Сумма 1991-1995	1.82	0.84

* – Проведено коренное улучшение луга.

** – Начато его использование.

С момента использования травостоев окультуренного пастбища в течение последующих пяти лет предотвращенная индивидуальная доза от молока составляет 0,98 mЗв. При этом вклад молочной компоненты на 5-й год в 4 раза ниже на окультуренных пастбищах по сравнению с естественными.

4. ВКЛАД ЗАГРЯЗНЕННЫХ ТЕРРИТОРИЙ ЧЕЧЕРСКОГО РАЙОНА В ФОРМИРОВАНИЕ КОЛЛЕКТИВНОЙ И ИНДИВИДУАЛЬНОЙ ДОЗ НА ОСНОВЕ ОЦЕНКИ ПОТОКОВ РАДИОНУКЛИДОВ ИЗ РАЗЛИЧНЫХ ЭКОСИСТЕМ

Как правило, территория, на которой проживает население, представлена несколькими экосистемами, среди которых сельскохозяйственные угодья (пашня, естественные и культурные луга и пастбища), леса, болота, водоемы.

Продукция, получаемая в этих экосистемах, распределяется как внутри загрязненной территории, так и экспортируется за ее пределы. В зависимости от площадей и продуктивности сельскохозяйственных угодий экспортируемая часть продукции, используемой в пищевых целях, варьирует в пределах 70-90% от валового производства.

На основании разработанной модели [1] проведены расчеты потоков радионуклидов, выносимых из аграрных и естественных экосистем территории Чечерского района в 1995 году (табл.III).

Таблица III

Оценка потоков ^{137}Cs из сельскохозяйственных и естественных экосистем Чечерского района ($\sigma_{ср.}{}^{137}Cs$ = 405 кБк/м²)

Вид продукции	Площадь $S*10^6$ м²	Прод.-ность $m*10^{-3}$ кг/м²	Вал. сбор $M*10^6$ кг	Коэфф.п.-да $K_п*10^{-3}$ м²/кг	Активность, $Q*10^6$, Бк	
					суммарная	экспорт
Зерновые	133	170	22.7	0.10	917	303
Картофель	34	1140	38.6	0.05	781	237
Кормовые	13		24.1	0.05	519	–
Солома	133	680	90.7	0.20	7336	–
Сено (пашня)	90	350	31.4	0.10	1271	–
Сено (луг)	115	300	34.5	3.0	46927	–
Молоко	–	–	13.3	–	1192	776
Мясо	–	–	2.5	–	817	732
Грибы	575	0.64	0.37	30.0	4467	3646
Ягоды	575	0.60	0.35	5.8	810	509
Дичь	575	0.10	0.06	2.6	61	–
Рыба	15	0.50	0.008	2.6	8	–
		Всего:	сельсхоз	продукция	59760	2048
		Всего:	естеств.	экосистемы	5346	4155
		Суммарный	вынос		65106	6203

Суммарный вынос радионуклидов ^{137}Cs и ^{90}Sr сельскохозяйственной продукцией и дарами природы зависит от плотности загрязнения на территории и продуктивности экосистем и распределяется между кормами для животноводства и пищевой продукцией, включая дары природы, в примерном соотношении 0,9:0,1. Следовательно, 90% радионуклидов, вовлеченных в сельскохозяйственную продукцию (корма) не выходят за пределы загрязненной территории. Остальные 10% активности могут участвовать в формировании коллективной дозы (табл.IV)

Таблица IV

Расчет коллективной и индивидуальной доз внутреннего облучения продукцией, произведенной на территории Чечерского района($\sigma_{ср.}{}^{137}Cs$ = 405 кБк/м²; $\sigma_{ср.}{}^{90}Sr$ = 10 кБк/м²)

Вид продукции	Суммарная доза		Экспорт. доза		Индивид. доза	
	^{137}Cs 1год чел.-Зв	^{90}Sr 70лет чел.-mЗв	^{137}Cs 1год чел.-Зв	^{90}Sr 70лет чел.-mЗв	^{137}Cs 1год µЗв	^{90}Sr 70лет µЗв
Зерно (мука)	7.5	230	6.4	198	61	1.1
Картофель (очищенный)	4.5	34	3.3	24	67	0.2
Молоко (цельное)	16.7	34	10.9	22	330	0.7
Мясо	11.4	2.5	10.3	2.3	67	0.006
Грибы (переработка)	12.5	0.21	10.2	0.17	130	0.002
Ягоды(сок варенье)	5.7	0.31	3.6	0.19	120	0.006
Дичь	0.8	0.07	–	–	50	0.004
Рыба	0.1	0.009	–	–	6	0.001
С/х продукция	40.1	300.5	30.9	246.3	530	2.006
Ест. экосистемы	19.1	0.6	13.8	0.36	310	0.013
Сумма	59.2	301.1	44.7	246.36	830	2.019

Расчеты показали, что молоко, зерно , картофель и овощи , произведенные в хозяйствах Чечерского района (13 колхозов и совхозов), средняя плотность загрязнения территории которого 405 кБк/м², могут сформировать коллективную дозу 40 чел.-Зв. Вклад цельного молока при этом составляет 16.7 чел.-Зв. Так как на месте потребляется только 25% произведенной продукции, то район экспортирует 30 чел.-Зв в год.

По этой модели выполнен другой вариант расчета, предполагающий использование контрмер в звене почва-растение на пашне, улучшение кормовых угодий и сохранение их продуктивности [2,3,4]. Сравнительная оценка двух вариантов расчета представлена в таблице V.

Таблица V

Эффективность проведения комплекса контрмер для снижения коллективной дозы, экспортируемой из Чечерского района

Вид продукции	S га	P кг/га	$K_п \cdot 10^{-3}$ м²/ кг	Сумма Q, Мбк	Процесс переработки	Экспорт Q, (%)	Экспорт дозы чел.-Зв
Без контрмер							
Зерно	13300	1700	0.1	917	-	50	6.4
Картофель	3400	11400	0.05	785	-	30	3.3
Молоко	3500	1640	0.51	1190	-	70	11.8
Мясо	8000	120	2.1	817	-	90	10.4
Сумма							31.9
Контрмеры в звене почва- растение							
Зерно	13300	2000	0.08	862	50	6.1	
Картофель	3400	14000	0.04	771	-	30	3.3
Молоко	3500	3800	0.15	809	-	70	8.0
Мясо	8000	300	0.6	590	-	90	7.5
Сумма							24.9
Переработка							
Зерно (20% спирт)	13300	2000	0.08	862	0,01	50	4.9
Картофель (крахмал)	3400	14000	0.04	771	0.02	30	0.07
Молоко (сливки)	3500	3800	0.15	809	0.05	35	0.2
Молоко (масло)	3500	3800	0.15	809	0.01	35	0.04
Мясо(*)	8000	300	0.6	590	-	90	2.7
Сумма							7.91

(*) - заключительный откорм

Контрмеры в звене почва-растение приводят к незначительному снижению экспортируемой дозы за счет основных продуктов питания, обусловленной уменьшением удельной активности кормов с лугов и пастбищ, а следовательно коллективной дозой, формируемой мясом и, что особенно важно, молоком (на 40%).

Если цельное молоко перерабатывается на масло [5], то экспортируемая доза уменьшается до 20 чел.-Зв/год. Переработка зерна в спирт и картофеля в крахмал могут снизить экспортируемую коллективную дозу до 15 чел.-Зв/год. Мероприятия по организации заключительного откорма мясного скота [6] обеспечивают кратность снижения коллективной дозы почти в 4раза.

Таким образом, контрмеры в звене почва-растение эффективны для снижения индивидуальных доз населения , проживающего на загрязненной территории. Для снижения коллективной дозы наиболее существенный вклад вносит процесс переработки произведенной продукции.

5. ЗАКЛЮЧЕНИЕ

Реальная оценка радиационной ситуации и прогноз ее ослабления позволяют заключить, что загрязненная территория может быть реабилитирована в случае применения комплекса мер организационного и специального характера, обеспечивающих в течение ближайших лет снижение индивидуальных доз до 1 мЗв в год. Для снижения индивидуальных и коллективных доз внутреннего облучения существуют надежные и управляемые контрмеры, применение которых экономически целесообразно и эффективно. Переработка произведенной продукции на месте может значительно снизить вклад загрязненных территорий в формирование коллективной дозы населения республики. Поэтому одной из организационных контрмер при реабилитации загрязненных территорий является развитие пищевой перерабатывающей промышленности.

В связи с тем, что в рамках государственной программы ликвидации последствий аварии на ЧАЭС правительство республики выделяет средства для финансирования контрмер в сельскохозяйственном производстве, радиологическая реабилитация загрязненных территорий в настоящее время реальна и в дальнейшем может стать основой для восстановления экономического потенциала административного района в целом.

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STRATEGY FOR PROTECTING CITIZENS OF BELARUS LIVING IN AREAS CONTAMINATED AS A RESULT OF THE CHERNOBYL ACCIDENT

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XA9745814

СТРАТЕГИЯ МЕР ЗАЩИТЫ НАСЕЛЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ, ПРОЖИВАЮЩЕГО НА ТЕРРИТОРИЯХ, ЗАГРЯЗНЕННЫХ В РЕЗУЛЬТАТЕ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АЭС

В.И. Тернов

Национальная комиссия Беларуси по радиационной защите

Несмотря на то, что после аварии на ЧАЭС прошло 10 лет, разработка и реализация адекватных мер по дальнейшей минимизации медико-биологических последствий ее, остается актуальной.

Исходя из этого , в апреле 1995года Национальная комиссия Беларуси по радиационной защите предложила для осуществления "Концепцию защитных мер в восстановительный период для населения, проживающего на территории Республики Беларусь, подвергшейся радиоактивному загрязнению в результате чернобыльской катастрофы".

Основополагающие позиции Концепции опираются на:

1. Констатацию факта вхождения Республики Беларусь в восстановительный этап ликвидации последствий аварии на ЧАЭС;

2. Положение о том, что в основе наблюдаемого деформирования здоровья населения , проживающего в зоне радиоактивного загрязнения, лежит механизм сочетанного воздействия на самогенез ряда неблагоприятных факторов, появление которых привело или косвенно связано с аварией на ЧАЭС.

При этом основные положения Концепции сводятся к следующему:

1. Анализ современной радиационной ситуации находится на восстановительном этапе минимизации последствий аварии. Исходя из этого и должны строиться все меры защиты населения.

2. Определяется, что главными целями радиационной защиты являются дальнейшее уменьшение вероятности развития у нынешнего и будущих поколений жителей стохастических эффектов путем неуклонного снижения индивидуальных и коллективных доз "аварийного" облучения.

3. Основным критерием для принятия решения и проведения защитных мероприятий, их характера и объема, является годовая эффективная доза (ГЭД), получаемая жителями. При этом, под этой дозой подразумевается среднегодовая эффективная доза жителей конкретного населенного пункта, включая и критическую группу.

4. Проведение мероприятий радиационной защиты должно строиться на строгом соблюдении принципа оптимизации - недопущении таких шагов, которые бы приносили больше вреда, чем пользы. При этом, приоритетность

проведения защитных мероприятий должна, как правило, определяться по критерию "предотвращенная коллективная доза";

5. Для практической реализации основных мер радиационной защиты, определения целесообразности очередности, характера и объема защитных мероприятий Концепция предполагает градацию населенных пунктов и их ареалов на 3 следующие категории в зависимости от значения годовой эффективной дозы аварийного облучения:

- населенные пункты, где ГЭД не превышает 1 мЗв. В этих населенных пунктах и прилегающих территориях жизнь и хозяйственная деятельность по радиационному фактору не ограничивается, а указанная доза предлагается допустимой. На таких территориях предлагается проводить радиационный мониторинг объектов окружающей среды, продуктов питания и питьевой воды с целью оценки доз облучения и осуществления при необходимости локальных мер защиты, основанных на принципе АЛАРА;

- населенные пункты, где ГЭД находится в интервале от 1 мЗв до 5 мЗв. Здесь, а также на прилегающих территориях наряду с мониторингом окружающей среды, сельскохозяйственной продукции и воды, проводятся обоснованные (оптимизированные) мероприятия по радиационной защите;

- населенные пункты, где население может получить ГЭД, превышающую 5 мЗв. Проживание здесь людей не рекомендуется, а хозяйственная деятельность ограничивается. Следует отметить, что определение данного дозового предела в качестве недопустимого, не опирается на современную теорию и практику радиобиологии, а лишь фиксирует реально достигнутый в республике уровень радиационной защиты населения;

6. Концепция предлагает при оценке возможного влияния на здоровье населения доз "аварийного" облучения в обязательном порядке учитывать степень опасности воздействия на его показатели комплекса неблагоприятных факторов различного характера.

7. Оговаривается важность и необходимость проведения мероприятий, направленных на медико-биологическую и социально-психологическую реабилитацию населения, проживающего на территориях, загрязненных радионуклидами. При этом в Концепции заложена необходимость продолжения проведения таких мер , в том числе, и к населению, у которого доза облучения уже не превышает 1 мЗв. Важным компанентом профилактики возможности появления негативных медико-биологических проявлений рассматривается высокий уровень оказания медицинской помощи, широкое оздоровление населения, обеспечение доброкачественными продуктами питания и другие атрибуты, входящие в понятие "здоровый образ жизни".

8. Концепция акцентирует внимание на необходимость решения круга научных и практических проблем, связанных с реабилитацией загрязненных радионуклидами территорий и постепенному возвращению населения на отчужденные земли с восстановлением на них полномасштабной деятельности.

RADIATION DAMAGE TO THE THYROID AND METABOLIC CHANGES IN CATTLE IN THE INITIAL AND REMOTE PERIOD AFTER THE CHERNOBYL ACCIDENT

XA9745815

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INTRODUCTION

The initial period after the Chernobyl accident was the most dangerous for animals kept in the zone of radiactive contamination. Dose burdens from I-isotopes on the thyroid gland of cattle in the initial period after the accident contributed significantly into the alteration of the hormonal status, physiological state and productive qualities of cattle on farms of the Gomel area of Belarus.

MATERIALS AND METHODS

To study the remote consequences of the radiation exposure of the thyroid in the initial period after the accident in the 30 km zone at 9-12 km distance from the destroyed atomic reactor 397 heads of cattle of black-motley race aged 1.5-2 y were kept for 2.5 months. According to the tentative estimation the dose absorbed by the thyroid amounted to 270-280 Gy (the 1st group).

The second group of animals (cows) aged 5-8 y grazed on the pasture for 2 months at 15-20 km distance from the Chernobyl NPP. The tentative dose absorbed by the thyroid amounted to 180-190Gy.

For the comparative estimation of physiological parameters and productive indices the animals-analogues from the state farm "Oktyabrskiy" in the "clean" zone of the Gomel area were used (3d group).

RESULTS OF INVESTIGATIONS AND THEIR DISCUSSION

5 months after the accident the animals relocated from the 30 km zone showed the signs of general oppression, reduced response to external irritants, curly, messy and rumpled hair, laboured breathing, disorders of coordination of movements, fibrillary contractions of muscles, body temperuture reduction to 34,0-35,0 C. The majority of animals demonstrated the symptoms of exopthalmus, thickening of skin fold near the head, neck and lateral body surfaces from 12 to 17 mm, crooked posture, sternocostal, cranal and submaxillary oedemas, poor appetite, exhaustion, absence of the cud and weakened rumination. 40% of animals demonstrated disturbances of the frequency and rythm of heart contractions and deviations between values of systolic and diasystolic heart tones. The changes of clinical symptoms listed above aggravated when the ambient temperature dropped. In the first year after the accident in animals relocated from the 30 km zone there were observed leucopenia, erythropenia, noticeable eosinophilia and sugar concentration in blood serum 2-3 times higher than normal.

The blood leucogram of animals showed the reduction of per cent concentration of the neutrophilic group and monocytes during the entire period of observation.

While the analysis of degenarative-destructive changes of cells in peripheral blood the qualitative changes of cells were observed (Table I)

Table I. Degenerative-destructive changes of cells in peripheral blood of cattle having the signs of radiation damage to the thyroid

Kind of pathology	Cells of blood, %		
	Lymphocytes	Neutrophiles	Monocytes
cytolysis	10.0	0.9	1.0
picnosis	5.0	1.0	-
vacuolation	7.5	-	50.0
fragmentation	-	12.0	-
chromatinolysis	4.4	2.7	-
double-nuclei lymphocytes	2.0	-	-
cariocraxix	1.0	-	-
hypersegmentation	-	50.0	-
atypical lymphocytes	8.0	-	-
Per cents	37.9	66.6	51.0

Thus, among the lymphoid cells in 10% of cases cytolysis was determined, and pycnosis and vacuolation in 5,0 and 7,0%, respectively. Atypical lymphocytes forms were registered in 8% of cases. Among the granulocytic series of form elements of blood, i.e. neutrophiles the changes had the character of hypersegmentation and fragmentation in 50 and 12 % of cases, respectively. Histiocyte range was characterized by increased vacuolation (50%).

Studies of natural resistance indicators of organism have shown that in 85% of relocated animals the lysozymic activity of blood serum reduced. While radioimmune investigations of blood serum the pronounced hypofunction of the thyroid that was characterized by the thyroid hormones (thyroxin, thriiodthyronin) reduction by 3 and more times as compared with the norm became apparent. Besides, these hormones were not determined in serum of 55-60% of animals in the first year after the accident. During the first three years in animals with the lethal outcome the thyroxin concentration in blood serum did not exceed 30,0 nmol/l that was 50% less as compared with the control ($p<0.01$)(Fig. 1). The triiodthyronin concentration in blood serum of animals with the lethal outcome had 2-3 fold reduction as compared with healthy animals (Fig. 2).

The reproductive functions of animals relocated from the 30 km zone in the first year after the accident were characterized by the disturbances of sex cycles, deliveries of still-born calves and calves with various anomalies. Thus, in the 1st group 6 calves were delivered by 30 heifers, 4 heads (66.6%) were lost, in the 2nd group 18 calves were delivered by 26 heifers, 7 heads (38.8%) out of them were lost. In the second year after the accident in the 1st group 26 heifers delivered 9 calves, 6 out of them were lost. In the 2nd group 26 heifers delivered 18 calves. In 1989 during 7 months 36 healthy calves with the average weight of 30-35 kg were delivered by 46 animals. In the third year after the accident in the 1st and 2nd group there were delivered 12 calves from 27 heifers and 20 calves from 27 heifers, respectively.

During the first two years after the accident calving of all the animals in the 1st and 2nd group proceeded with various pathological phenomena. The post-delivery period was characterized by grave endometritits. uterine hemorrhages and inflammatory processes. 2-3 weeks after calving in the majority of animals the lactation period finished and the hypotrophy of the mammary gland parenchyma developed. The average live weight of calves delivered in 1986-1987 was 12-17 kg. They exhibited weak development when compared with normal animals. Thus, calves (bull-calves born in 1986) exhibited the delayed growth, dwarfiness, non-proportional body development and thick and long hair integument. The live weight of them at the age of 2.5 y was only 140-150 kg.

The productive indices of animals were characterized by low values.

Thus, average daily weight gain of young animals in the 1st group was 180, 320 and 356 g in 1986, 1987 and 1988, respectively. and in the 2nd group the corresponding values were 240, 380 and

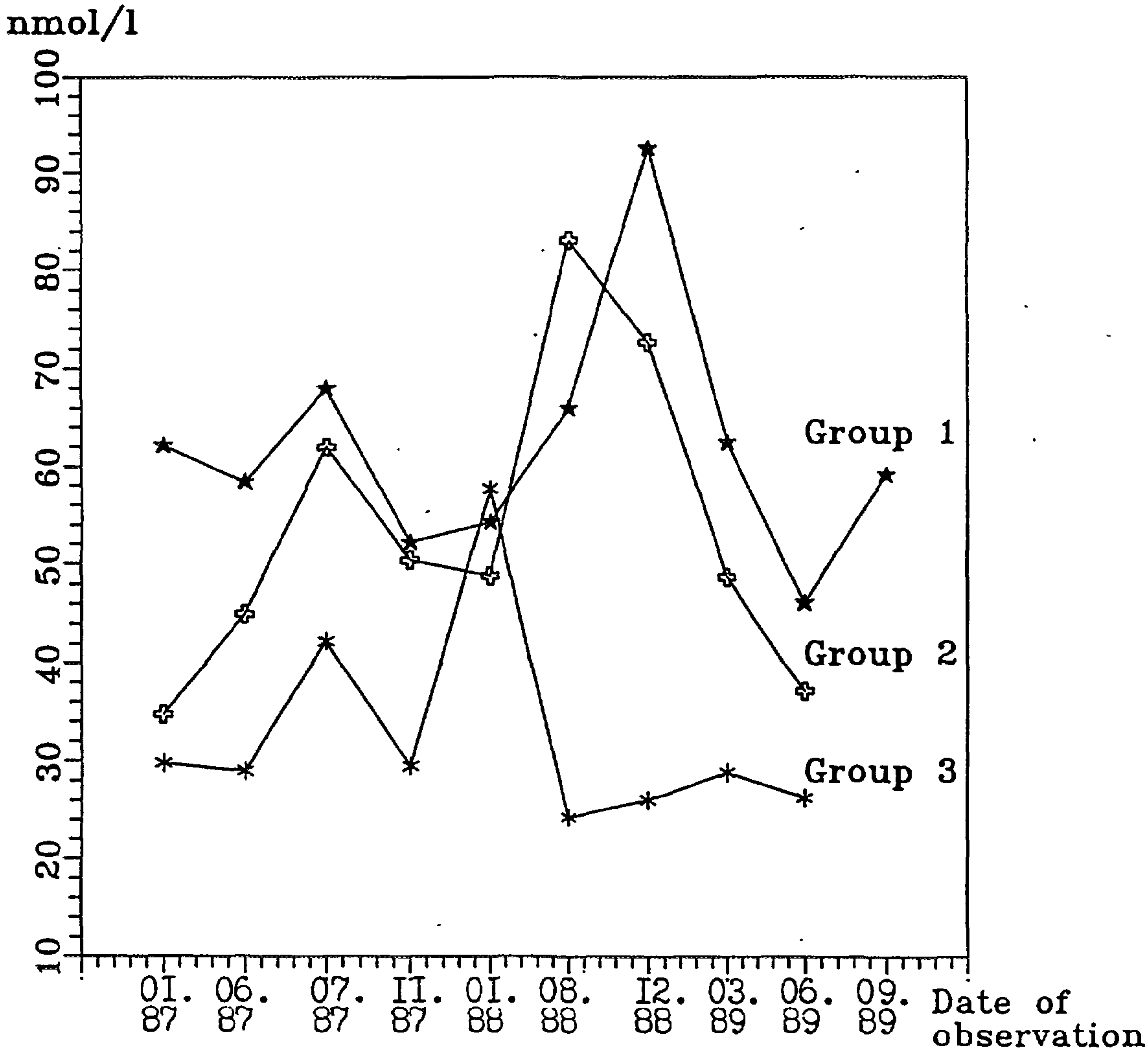

Fig 1. Dynamics of thiroxin concentration in blood serum of cows with symptoms of radiation affection of the thyroid

Note:

1 – control group of animals
2 – survived
3 – with lethal outcome

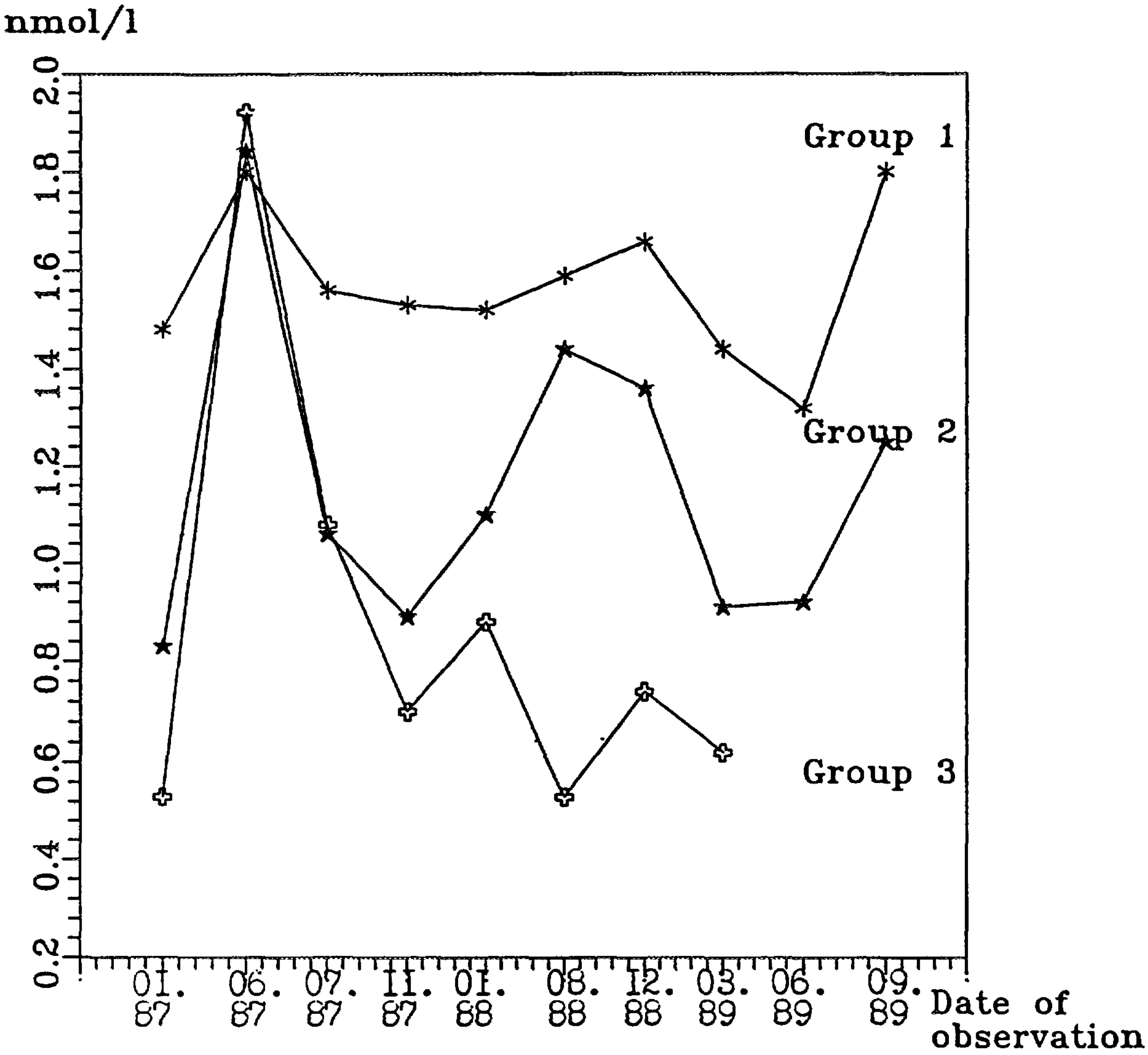

Fig 2. Dynamics of triiodthyronin concentracion in blood serum of cows with symptoms of radiation affection of the thyroid.

Note:

1 – control group of animals
2 – survived
3 – with lethal outcome

450. Whilst healthy young animals had average daily weight gain of 490, 470, 540 and 560 g in 1986, 1987, 988 and 1989, respectively. The average daily yield of milk in the 1st group was 2, 2.7 and 3.5 kg in 1986, 1987 and 1988, respectively. And in the 2nd group the corresponding values were 3.5, 4.0 and 6.0. Control animals had the average daily milk yield of 4-5 kg more as compared with animals having the sypmtoms of radiation damage to the thyroid.

Since October 1986 till March 1987 97 heads (22.6%) out of 397 heads in the 1st group were lost, 271 heads had to be slaughtered and 68 carcasses (25%) out of these were utilized. During the post slaughter examination of carcasses and pathologicanatomic autopsy the multiple gelatinous oedemas of subcutaneous cellular muscular tissue were discovered and mostly in the spots of deposition of fatty tissues were For the comparative estimation of morphological changes in the parenchyma of the thyroid the figure of the texture of this organ in a healthy animal is presented (Fig.3)

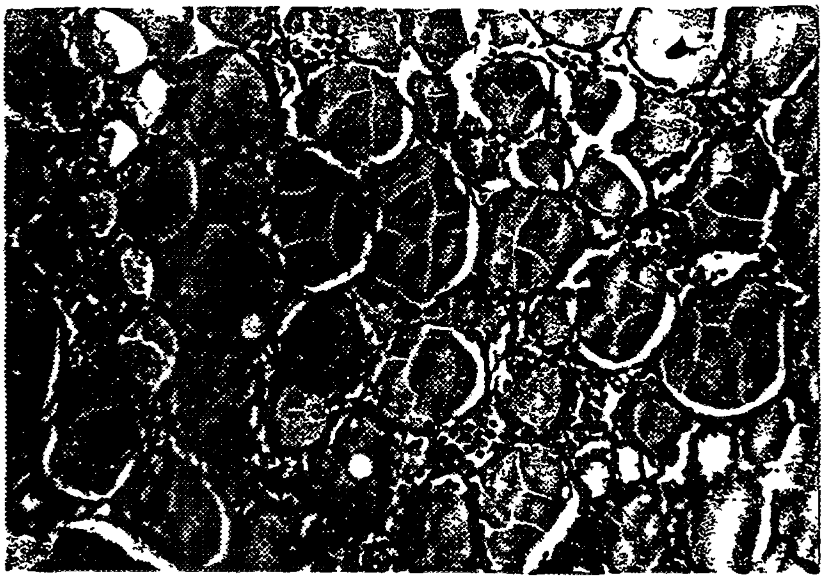

Fig. 3. The thyroid of a cow. Normal texture of parenchyma.
Colouring: hematoxylin-eosin. x70

In animals lost the thyroid gland was absent in 80% of cases, in the others it was shrunk in size and had a dense consistency and a whitish-grey colour. The tissue section did not exhibit lobes. The total necrose of specific glandular tissue and and the replacement of it by the cell-free connective tissue in the parenchyma of the gland (Fig. 4).

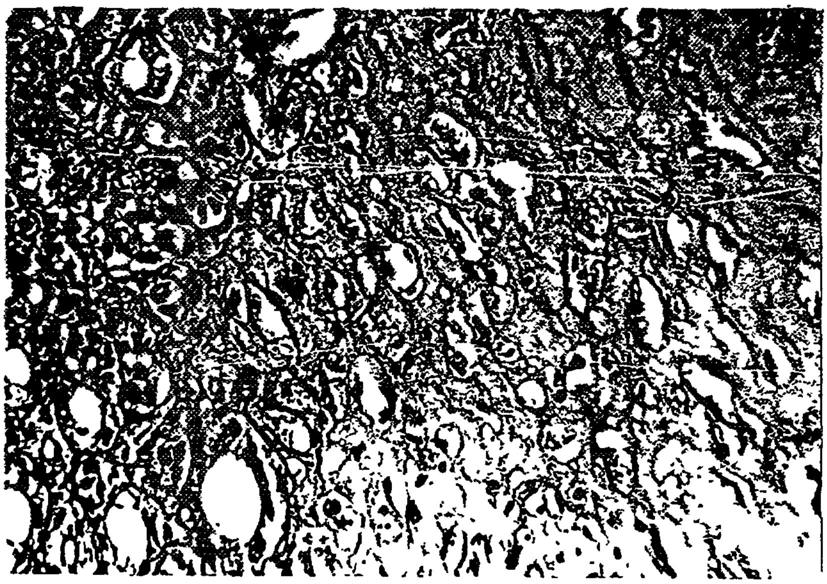

Fig. 4. The thyroid gland. Total necrose of the glandular tissue of the thyroid gland of a cow. Colouring: hematoxylin-eosin. x70.

Beside the vascular reaction the necro-dystrophyc changes of follicles epithelium in the form of vacuolation of cytoplasm and picnosis of nuclei, and also partial destruction of follicles and proliferation of glandular epithelium were observed. The increased concentration of interfollicular cellular tissue was registrated in some animals. Interfollicular cells surrounded follicles and partially replaced them. In the places of their accumulation appeared connective-woven fibres (Fig 5).

Fig. 5. The thyroid gland. Necrodystriphic changes in the gland parenchyma. Colouring:hematoxylin-eosin. x70

So, in the thyroid gland of animals the atrophic, hypo- and hyperplastic processes were observed causing not only hyperthyroiditis but also the gland function drop (hypothyroiditis) and even its total absence of it (athyroiditis).

CONCLUSION

In cattle kept at 9-12 km distance (1st group) and 15-20 km (2nd group) from the destroyed atomic reactor for 2.5 months after the accidental release the radiation damage to the thyroid caused by the impact of radioactive I-isotopes were observed. According to the tentative estimations the doses absorbed by the thyroid of animals made 270,0-280,0 and 180-190 Gy. The degree of radiation pathology depended upon the dose of I-131 absorbed by animals and had the signs of myxedema, general oppression, exophthalmus, body temperature reduction for 1-2 C, disorders of coordination of movements, disturbances of heart activity and digestive functions. Leucopenia, eosinophilia, degerative-destructive changes of cells were not observed in the peripheral blood. The disfunction of the thyroid characterized by the sharp reduction of thyroid hormones concentration by 3 and more times as compared with the norm and also by necrodystrophic changes in the parenchyma of the organ was the most typical of the given animals.

In animals with the heavy degree of the radiation damage to the thyroid with lethal outcome (22.5%) the thyroid was absent (athyroiditis). The disturbances of reproductive functions, growth and development of young animals, productive indices were observed in sick animals. In 1990 young animals of the second generation were delivered by the survived animals and their physiological parameters met the normal values for the given kind of animals.

RADIATION ECOLOGY SITUATION IN THE 30 km ZONE IN BELARUS

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РАДИАЦИОННО-ЭКОЛОГИЧЕСКАЯ ОБСТАНОВКА 30-км ЗОНЫ БЕЛОРУССИИ

профессор Ролевич И.В.

Министерство по чрезвычайным ситуациям
и защите населения от последствий
катастрофы на Чернобыльской АЭС
Республики Беларусь

30-км зона (или зона отчуждения) расположена на юго-востоке Белоруссии и имеет площадь 170 тыс.га. Из них 58 тыс.га занимают лесные насаждения. Земли этой зоны с мая 1986 г. выведены из хозяйственного оборота и вошли в состав Полесского радиационно-экологического заповедника. Радиационная обстановка в ней определяется цезием-137 с плотностью загрязнения в среднем 1480 и более кБк/кв.м (колеблется от 185 до 1850000 кБк/кв.м) - на 52% территории она составляет 555-35700 кБк/кв.м, стронцием - 90 с плотностью загрязнения более 111 кБк/кв.м (60-70% территории), достигающей 630 кБк/кв.м, и изотопами плутония (3,7-140 кБк/кв.м). Содержание америция - 241 в почве составляет 0,074-18 кБк/кв.м. Обнаруживаются также цезий - 134, рутений - 106, церий - 144, сурьма - 125 и др. В верхнем почвенно-растительном слое содержится до 90% выпавших изотопов в различных формах. Для стронция - 90 характерно превалирование обменных форм. Около 80% выпавших "горячих" частиц имеет топливную природу. Содержание стронция - 90 в них колеблется от 0,1 до 17 Бк/част., плутония - 0,001-0,09 Бк/част. Загрязнение почв лесных массивов отмечается большой пестротой и составляет 1480 - 37000 кБк/кв.м. Древесные растения, в основном, обладают высокой удельной радиоактивностью и непригодны для хозяйственного использования ($0{,}44 \cdot 10^6$ кубм и достигают уровня радиоактивных отходов). Миграция радионуклидов осуществляется за счет абиогенных и биогенных факторов. Выход радионуклидов из "горячих" частиц осуществляется за счет их выщелачивания. Указанный процесс возрастает со временем. Растительность аккумулирует до 2-5% радионуклидов почвы. Накопление и распределение водообразующих радионуклидов по органам и тканям диких животных идет неравномерно. Отмечается коренная перестройка состава и структуры фито-и зооценозов. В докладе дается оценка содержания цезия-137 и стронция-90 на затапливаемых площадях, в водотоках и донных отложениях и анализируется возможность поступления радионуклидов в грунтовые воды. Прогнозируется повышение масштабов загрязнения грунтовых вод и невозможность использования их в качестве источника хозяйственно-питьевого водоснабжения. В весеннее половодье речным стоком может быть вынесено в Киевское водохранилище 6-10% цезия-137 и стронция-90. На данной территории не разрешается проживание людей и любая хозяйственная деятельность. Воздействие радионуклидов на организмы сводится:

-к внешнему облучению от радиоактивных выпадений;

-к ингаляционному поступлению одного или смеси радионуклидов.

На наиболее загрязненных участках местности при работах на открытом воздухе работающие могут в течение года получить дозы до 0,15 Зв. В воздухе концентрация цезия-137 может достигать $2{,}5 \cdot 10^{-11}$ Ки/л, плутония - $7 \cdot 10^{-14}$ Ки/л. Содержание радиоцезия в организме работников заповедника в 67% случаев составляет 0,1-1 мк Ки, в 11% - выше 1 мк Ки.

В соответствии с рекомендациями Белорусских ученых предусматривается:

-сохранить режим жесткой изоляции зоны с сохранением в обозримом будущем статуса заповедника, предотвращающий бесконтрольный доступ, ввоз и вывоз;

- на территориях со сравнительно невысокими плотностями радиоактивного загрязнения, которые выведены из сельскохозяйственного оборота, но не включены в состав Полесского радиационно-экологического заповедника, целесообразно создать "буферную" зону;

- учитывая уникальность характеризуемого объекта, необходимо продолжить комплексные фундаментальные научные исследования механизмов биогеохимического круговорота радионуклидов в экосистемах, действия хронического облучения на биологические объекты и особенностей формирования биологического разнообразия в условиях снятия хозяйственной нагрузки;

- для контроля за состоянием природно-технических систем и предотвращения нежелательных стихийных явлений предусматривается проведение комплекса мероприятий, включающих:

научное обеспечение содержания зоны отчуждения;

проведение противопожарных мероприятий;

управление гидротехническими сооружениями;

поддержание в работоспособном состоянии мостов, высоковольтных линий, трансформаторных подстанций, систем связи, дорог к ключевым объектам;

- предлагаемый комплекс мероприятий не исключает одновременного проведения в зоне отдельных работ по захоронению местных продуктов дезактивации (с учетом горно-геологических условий местности, радиационной ситуации и складывающихся регенерационных фито-и зооценозов). Мероприятия по перезахоронению уже имеющихся могильников следует считать неэффективными, так как ведут, с одной стороны, к увеличению коллективной дозы, а с другой - существенно не улучшают ни экологическую, ни радиационную обстановку;

-обеспечение нормальных условий деятельности находящегося на территории зоны отчуждения персонала;

-организовать в центральной северной части зоны отчуждения (н.п.Нежихов - Выгребная Слобода), которая представляет собой охваченный интенсивной мелиорацией крупный массив низинного болота общей площадью от 15 до 20 тыс.га, контроль за водным режимом территории без поддержания в рабочем состоянии мелиоративных систем;

-рассматривать северо-западную часть зоны, представленную в основном хвойными массивами средних размеров, средневозрастными и приспевающими (территория имеет значительные запасы лекарственных растений, ягодных растений, грибоносных площадей, здесь обитает большое количество копытных), в качестве зоны ограниченного хозяйственного использования, не приводящего к загрязнению окружающей среды, с сохранением заповедного режима в местах произрастания редких видов растений и обитания животных;

-предусмотреть в юго-западной части зоны (практически вся Наровлянская зона), имеющей невысокую степень загрязнения, характеризующейся отсутствием ценных и охраняемых видов растений и животных, а также научных полигонов, организационные и технические решения по восстановлению хозяйственной деятельности;

-установить строгий заповедный режим в центральной и южной части зоны. Она является наиболее загрязненным участком заповедника и представляет значительный научный интерес. Здесь преобладают лесные насаждения площадью 25 тыс.га. Имеется большое количество научных полигонов;

-пойму р.Припять (территория ограничивается в левобережной части линией Кожушки-Оревичи, в правобережной - Довляды-Тешков) следует отнести к охраняемым территориям и выделить в качестве санитарно-защитной зоны. Территория характеризуется небольшой плотностью загрязнения, значительным количеством озер и проток. Площадь 30-35 тыс.га.

В обозримой перспективе использовать земли бывших сельскохозяйственных угодий I и II зоны загрязнения для производства сельскохозяйственной продукции нецелесообразно по природным условиям, экономическим причинам и опасности вторичного загрязнения радионуклидами прилегающих территорий при распашке преобладающих песчаных почв. Предлагается использовать эти земли в качестве буферной зоны с одновременным их залесением. Отдельные небольшие участки высокоплодородных почв I и II зон загрязнения могут быть использованы только в экспериментальных целях на основании Положения о заповеднике. Полученная продукция при соответствующем радиационном контроле используется преимущественно на удовлетворение внутрихозяйственных нужд заповедника или реализуется в качестве технического сырья.

При проведении работ на территории должен осуществляться радиационный контроль с целью соблюдения норм радиационной безопасности и получения информации о дозах облучения.

RADIOLOGICAL ASSESSMENT OF LONG LIVED RADIONUCLIDES TRANSFERRED THROUGH AQUATIC PATHWAYS

XA9745817

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INTRODUCTION

This study is based on the work carried out at: 1) the Environmental Radioactivity Laboratory of the Institute of Nuclear Technology - Radiation Protection of the National Centre for Scientific Research"Demokritos" - Greece, in the frame and on behalf of MARINAMED project of the EU, 2) the Laboratory of Comparative Radioecology and Molysmology of the Department of Radiation and Chemical Biology of the A.O. Kovalevsky Institute of Biology of the Southern Seas - Ukraine and 3) the Radioecology Laboratory of the General Department of Biology and Physiology of the University of Parma - Italy in the framework of the "Adriatic Scientific Cooperative Programme". Published work on the issue, as well as, data on aquatic pathway transfer of radionuclides of the work performed in the above Laboratories, appropriately treated, were used for this short evaluation of the issue.

The long term impact of the Chernobyl accident, from the radioecological aspect is focused on the aquatic pathways since they are the main routes of the late Chernobyl debris migration as the aquatic basins act as a final reservoir for the long lived radionuclides released in the environment.

In this study the main routes of the late Chernobyl debris from the pollution source to the Mediterranean are evaluated, in relation to the long lived radionuclides ^{137}Cs mainly, while some data on ^{90}Sr dispersion are also given. The decrease trend of the Chernobyl impact on a closed aquatic system is also evaluated in relation to the ^{137}Cs deposition during May 1986 over Greece and following measurements during 1987 and 1989.

Sampling in the marine and freshwater environment was performed by the above mentioned Laboratories in the framework of their research and monitoring programmes. Samples were radiochemically treated and measured in low level-gamma spectrometry and low-level beta counting systems.

Marine environment

The Chernobyl Nuclear Power Plant area is the land-based source of radionuclide chronic pollution of the Black Sea through the Pripyat river and the Dnieper river. In addition, radioactive pollutants of terrestrial origin are carried in by the Danube, Dniester, Dnieper river outflows and drainage system procedures (1).

Investigations on the North Aegean Sea water dynamics, have indicated that the Black Water outflows from the Dardanelles with a minimum salinity of 29 and has an anticlockwise vorticity within the surface layer.The volume of the Black Sea water entering the Aegean through the Dardanelles (200-700 km^3/y) is insignificant compared to the total water volume of the North Aegean Basin (Athos Basin), which is estimated to be approximately 11 000 km^3 (2). However, its influence appears throughout the Aegean Sea, as it is traced into the Cretan Sea, towards the northern coast of Crete, and into the Southeastern Ionian Sea near the western Cretan Arc straits (3).

Therefore, as the Black Sea is linked to the Mediterranean through Dardanelles, its purification procedure towards the North Aegean Sea results to radioactive pollution of the Aegean Sea from the late Chernobyl debris carried in by rivers and drainage system outflows to the Black Sea.

The Adriatic Sea, with respect to the distance from the pollution source, is one of the seas significantly contaminated by the accident (4). As adjoined with the Ionian Sea is environmentally familiar with the Aegean Sea whereas it is far from the pollution source term. This area is considered as the background reference area for the pollution evaluation of the late Chernobyl debris through the aquatic pathways in the impact and influenced marine areas.

The following ^{137}Cs input from Chernobyl fallout in the Black Sea and the Eastern Mediterranean is estimated to be 2400 TBq for the Black Sea, 820 TBq in the Aegean Sea 600 TBq in the Ionian Sea (60 TBq in the zone of 50 km across the Greek coasts) and 1900 PBq in the Adriatic Sea. The effective mean residence time of the Chernobyl ^{137}Cs in the Black Sea is estimated to be 25-30 years. Based on studies during the period 1987-1992, it has been determined that the annual outflow of ^{137}Cs into the Mediterranean Sea is about 1.62-1.84% of its inventory in the 0-50 m layer of the Black Sea. The expected total outflow from the Black Sea to the North Aegean Sea through the Bosporus and Dardanelles is 246 Tbq (5, 6, 7).

Several studies have been also performed on ^{90}Sr migration in the Black Sea and the Aegean Sea (8). Based on these studies, as ^{90}Sr is a much more moveable radionuclide, it is able to penetrate during long period of time from the Chernobyl area (via Pripyat and Dnieper rivers, the Black Sea and the Sea of Marmaras) to the North Aegean Sea. It has been estimated that by the end of 1992, 60 Tbq of ^{90}Sr was discharged to the Mediterranean from the Black Sea. This value accounts for 73% of an amount of radiostrontium delivered together with the Dnieper and the Danube rivers during this period (0.8% of total amount of radiostrontium totally released to the environment after the Chernobyl accident). Therefore, a significant part of annual ^{90}Sr flux migrates from the Black Sea into the Mediterranean too.

The long term impact of the Chernobyl Nuclear Accident to the Eastern Mediterranean can be explained in terms of two main sources of ^{137}Cs and ^{90}Sr, the initial deposition to the Black Sea and the transfer of radioactive material by surface and ground water starting from the Kiev reservoir and ending at the Northeastern part of the Black Sea and the terrestrial material carried in by the rivers Dnieper, Dniester, Danube etc., as well.

Freshwater environment

Considering the freshwater water bodies , they are known to be subjected to stronger influence of large accidental releases due the ecological parameters of freshwater ecosystems. Nevertheless, following the Chernobyl accident, high concentrations up to 520 000 Bq/kg for ^{137}Cs and up to 840 Bq/kg for ^{90}Sr (9) have been observed in the Chernobyl Nuclear Power Plant cooling pond in Ukraine. Radiocaesium and radiostrontium level gradients with time have also been studied in Ukraine (10). The observed ^{137}Cs and ^{90}Sr levels decrease from the Kiev reservoir to the Dnieper estuary.

The measured values in the freshwater systems in the impact areas up to 7 years after the accident, vary from several hundreds to thousands Bq/m^3, which, although are lower than the USSR permitted maximum concentration for a limited part of the population. Nevertheless, these values are of radioecological significance from the point of effects on aquatic biocoenoses.

Radioactivity monitoring of shallow brackish water areas in the Black Sea near the Danube mouth has shown a strong influence of the Chernobyl fallout in the Razim - Sinoe lagoon an area influenced by the Danube outflow.

Elevated levels of radiocaesium (^{137}Cs + ^{134}Cs) up to 800 Bq/kg in fish) have been observed also in abiotic and biotic components of the Greek lakes . During 1986, the bioaccumulation of radiocaesium by lake freshwater fish has been found to be up to two orders of magnitude higher than those observed in marine species (11). As lake environment is a closed system, the total caesium measurements during the period 1986-1989 in a number of fish species caught from several lakes. in Greece are used to estimate the time dependence elimination of Cs from lake fish, as an example for the late Chernobyl impact evaluation (12).

RESULTS AND DISCUSSION

Marine environment

The ^{137}Cs levels in surface sea water for 1993 are illustrated in Fig. 1. We selected ^{137}Cs to show the late Chernobyl impact to the eastern Mediterranean, as it is a good example of a highly soluble radionuclide, whose marine chemistry has been well characterized - because of its relatively long half-life and previous studies on this major component of atmospheric nuclear weapon testing fallout.

As it is shown in Fig. 1, the ^{137}Cs levels in sea water in the wide areas of interest are as follows:

I). In the Black Sea, the area close to the source of impact , the concentrations of ^{137}Cs are up to 130 Bq/m^3. Considering the early Chernobyl impact, the ^{137}Cs concentrations in the Black Sea surface waters found to be elevated over its previous activity levels by a factor of 10 to 20 (17). It is found in some places in the Black Sea that surface water ^{137}Cs levels had jumped from 15 to 370 Bq/m^3. Based on our measurements, we estimated that ^{137}Cs levels of 1993 has decreased 3-5 times compared with the levels observed during 1986.

II). In the Aegean Sea, the levels observed before 1986, due to world wide fallout varied about an average 2. 58 ± 0. 27 Bq/m^3 (14). The Chernobyl deposition and the Black Sea discharge resulted during 1986, in an average ^{137}Cs level in the Aegean Sea surface water of than one order of magnitude higher than that reported previously. Our results show that 6 years after the Chernobyl accident the ^{137}Cs levels remain higher, owing to the discharging of the Black Sea.

III). In the Adriatic Sea, the concentration of ^{137}Cs in surface samples collected during the June 1986 was several times higher than the pre-Chernobyl levels (3 - 6 Bq/m^3) up to 88 Bq/m^3 (higher value detected in the northern part along the Italian coasts). Since 1989 concentrations of ^{137}Cs in surface sea water samples from Adriatic Sea were very similar to pre-Chernobyl values.

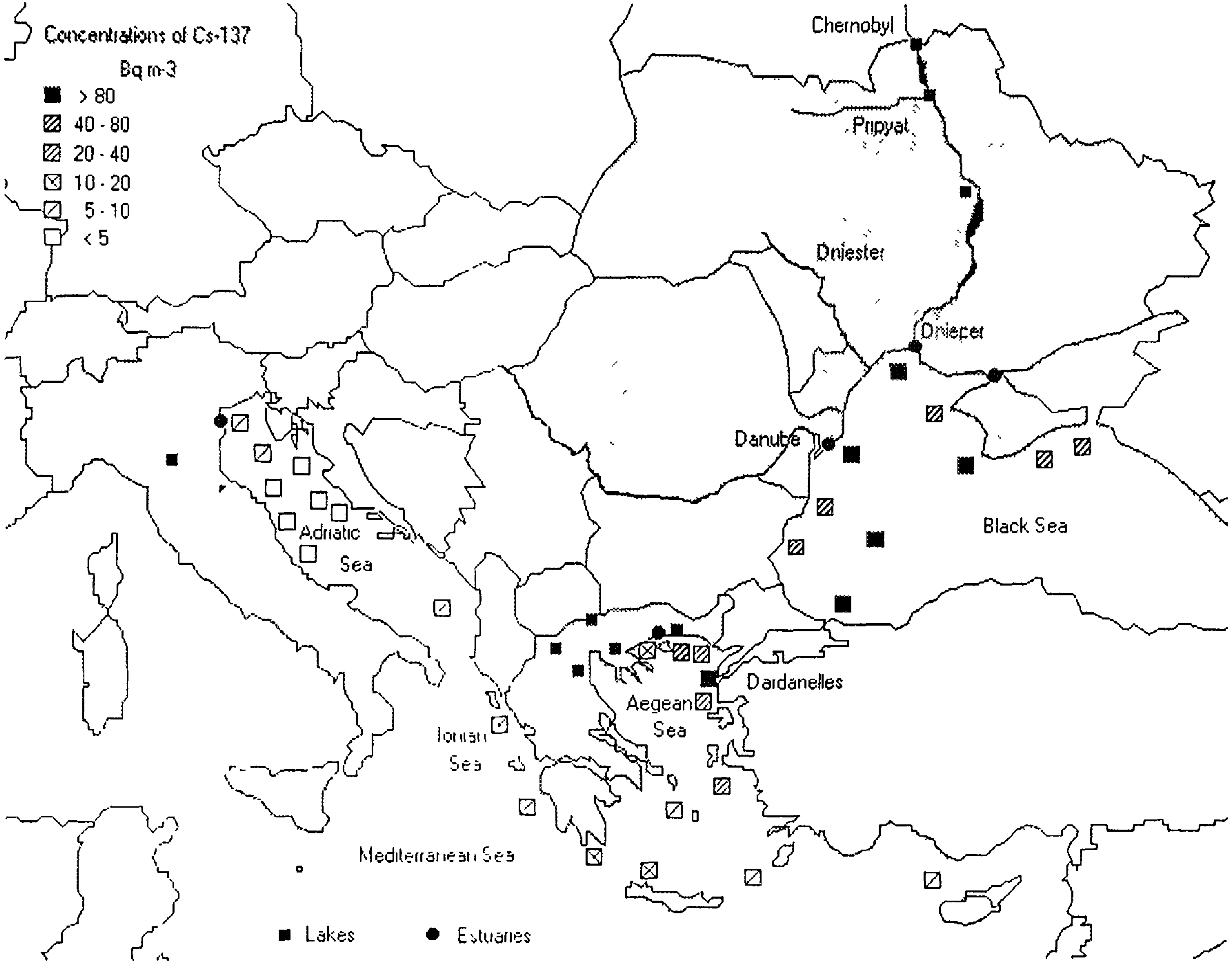

Fig. 1. Cs-137 levels in the areas of interest during 1992-93 (Adriatic Sea - 1990).

Considering the Black Sea water mass influence to the Aegean Sea (6), the velocity of the ^{137}Cs outflow for the 0-50 m depth interval in the Black Sea based on data 1987 - 1991 has been assessed by the exponential function:

$$v = 25.5\, e^{-0\ 103t}$$

V = velocity of ^{137}Cs outflow in TBq/y
t = m time period in years

Freshwater environment

I). Considering the impact area around Chernobyl, studies (15) on the annual average concentrations of ^{137}Cs and ^{90}Sr in the Pripyat and Dnieper Rivers during the period 1986 - 1991 has shown that:

The flood plain area of the Pripyat River in the close-in zone around Chernobyl Nuclear Plant is the primary potential source of contamination of waters. Nevertheless, the removal of ^{137}Cs by both rivers and ^{90}Sr by the Dnieper River decreases with time. As far as ^{90}Sr is concerned, no clear reduction of the radionuclide transfer can be observed. This is primarily due to the fact that ^{90}Sr is washed down to the river from the highly contaminated river plain and it is associated small lakes and streams. The total flux of radionuclides into the Kiev reservoir by the Pripyat and Dnieper Rivers during this period was estimated at 95.5 Tbq for ^{90}Sr and 110.2 Tbq for ^{137}Cs. However, although the ^{90}Sr contamination levels of the water bodies in the close-in area are over the permissible concentration levels, the calculations showed that, even with complete wash-down of radionuclides from the most contaminated section of the flood plain to the Pripyat and with complete transfer of exchangeable forms of radionuclides the bottom sediments of the cooling pool to the water, the concentrations of ^{137}Cs and ^{90}Sr in the Kiev reservoir r will not exceed the permissible concentration levels of 555 kBq/m^3 and 14.8 kBq/m^3 respectively.

II). In Greece, one of the European Countries significantly affected by the accident (16), the radioactive contamination of the lake ecosystems is potentially a radiologically important consequence of the accident. In the present work, the effects of ^{137}Cs and ^{134}Cs introduced into a number of major Greek lake ecosystems has been summarized, based on the work carried out during the years 1986, 1988 and 1989 (12). The concentrations in various lake fish species are evaluated in relation to the initial deposition and the "ecological half-lives" of caesium - T_e - of caesium in fish flesh (derived from the exponential fits of the decay-corrected values) and the ratios of total caesium concentrations in fish flesh (1988/1986) are estimated. The term "ecological half-life" is introduced to reflect the presence of various processes affecting the time-dependence of caesium concentrations in fish, such as the time-behaviour of the source term (e.g. delayed input due to weathering processes in the region of the lake), the caesium dynamics in the lake water (dilution, sedimentation, re-suspension) and the bioaccumulation of caesium by fish.

As it is shown in Fig. 2, the average concentration of total caesium in the fish flesh of species from each lake during June 1986 - C_L - is given versus D_L - the regional deposition of total caesium in the lake district. The correlation coefficient equals 0.98 and the regression relation (zero y-intercept type) is:

$$C_L\,(Bq\,kg^{-1}) = 0.021\, D_L\,(Bq\,m^{-2})$$

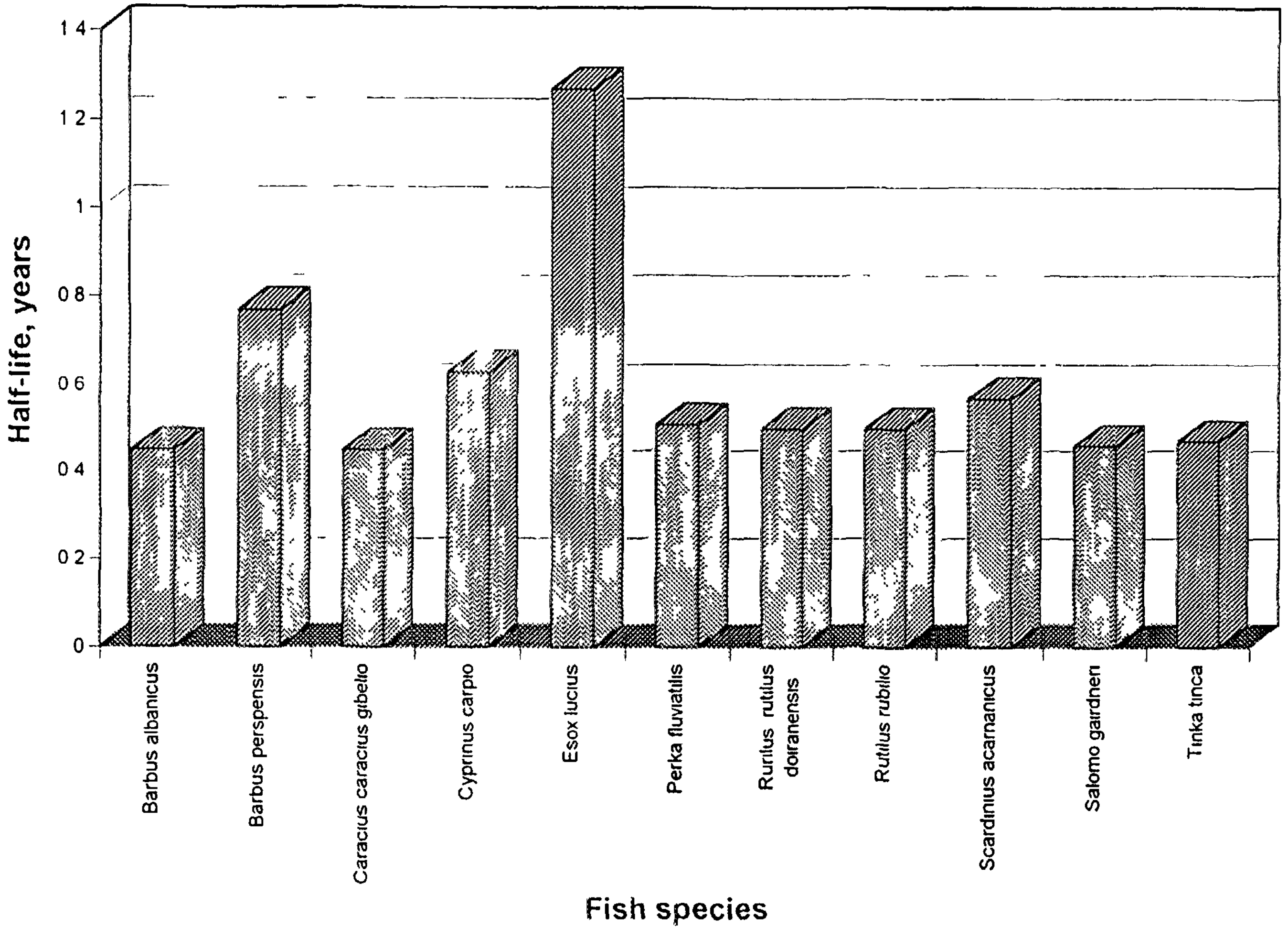

Fig. 2. Estimated ecological half-lives of radiocaesium in lake fish
(field studies in 7 Greek lakes)

Based on the effective half-live (calculated by our time series measurements of radio caesium in fish) the ecological half-lives were estimated as follows:

$$T_{eff} = T_e T_p (T_e+T_p)^{-1}$$

where T_e refers to all ecological processes affecting the concentrations of caesium in fish, except the radioactive decay and T_p is the physical half-life (due to the radioactive decay).

The derived ecological half-lives vary from 0.45 to 1.27 y with respect to the fish species.

As the T_c is the parameter needed for the estimation of the integrated concentrations in fish and of the committed effective dose equivalent from fish consumption, the determination of the effective half-lives in fish has besides the radioecological and radiological significance for people. The derived committed effective dose equivalent for the "critical group" is close to 400 μSv (12).

Authors' Note: *A proposal for further research on model migration of radionuclides in aquatic systems, the late effects on aquatic biocoenoses and the radiological impact assessment has been submitted for funancing in the frame of the Nuclear Fission Safety of the RTD programmes of the EU.*

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GEOGRAPHIC INFORMATION SYSTEMS FOR THE CHERNOBYL DECISION MAKERS IN UKRAINE

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1.0 INTRODUCTION

Following numerous national and international studies conducted on the overall impact of the 1986 Chernobyl nuclear power plant disaster, decision-makers of the affected countries have oriented their efforts on environmental clean-up and population safety. They have focused on activities leading to a better understanding of radionuclide contamination and to the development of effective environmental rehabilitation programs. Initial developments involved the use of domestic USSR technologies consisting of mainframe IBM computers and DEC minicomputers. Later, personal computers with imported software packages were introduced into the decision-making process [Prister et al., 1994]. Following the breakup of the former USSR, the Ministry of Chernobyl (MinChernobyl) was created in Ukraine in 1991. One of the Ministry's mandate was the elimination of the environmental after-effects of the Chernobyl disaster.

1.1 Inform-Chernobyl

The creation of MinChernobyl in Ukraine focused all activities surrounding the elimination of the Chernobyl disaster after-effects into one government structure similar to that of the Ukrainian Cabinet of Ministers. MinChernobyl activities also involves the cooperation among its member departments and with a number of other government Ministries and agencies, such as the Ministry of Atomic Energy, Ministry of Public Health, State Committee of Hydrometeorology, several departments of the Ukrainian Academy of Sciences, Main Administration of Geodesy, Cartography and Cadastre, and others. To facilitate the environmental management functions of MinChernobyl, a comprehensive system entitled Inform-Chernobyl was initiated. The system would be based on information technologies suitable for providing support in decision making and problem solving activities involved in the elimination of the Chernobyl disaster after-effects. Ukrainian managers established global and local objectives or directions for Inform-Chernobyl [Prister et al., 1994].

The global objectives provide decision-makers with the information necessary to develop policies for the effective, long-term management of the environmental effects of the Chernobyl accident. The objectives for Inform-Chernobyl are listed as follows:

1) calculate the radioactive pollution levels of milk and potatoes through related environmental parameters;
2) determine the optimal and economical management of the polluted territories for the cultivation of minimally contaminated agricultural commodities;

3) evaluate GIS and related technology for creating a full-scale Radio-ecological GIS (RGIS) for the Ukrainian territories affected by the Chernobyl disaster;
4) establish principles of integration for RGIS and Radio-ecological Decision Support System (RDSS).

For the shorter term, a number of local objectives were also defined for Inform-Chernobyl. They are listed as follows:

1) design and develop an integrated radio-ecological database (IRDB);
2) classify the contamination of natural resources by contamination type and level;
3) develop a land information system as a sub-system of RGIS and as a principal tool for environmental management;
4) integrate RGIS with spatial statistical analysis tools for the production of single and multi-variable contamination maps;
5) integrate RGIS with complex models of radio nuclide migration, in particular with modelling systems of radio nuclide migration in the hydrosphere and lithosphere;
6) integrate RGIS with multi-criteria evaluation methods in GIS as a mathematical base for achieving global objective 2).

1.2 Chernobyl GIS Pilot Project Objectives

The Chernobyl GIS Pilot Project was designed as a subsystem of RGIS. Therefore, the pilot project objectives were set up within the scope of the Inform-Chernobyl objectives. The objectives included:

1) installation of a suitable GIS in Kyiv;
2) training of local personnel on the operation of the system;
3) design and population of an integrated database;
4) development of GIS applications for the pilot project area relevant to the elimination of the Chernobyl disaster after-effects.

2.0 GIS PILOT PROJECT COMPONENTS

The Chernobyl GIS pilot project has been attached to MinChernobyl and housed in the Main Administration of Geodesy, Cartography and Cadastre (attached to the Cabinet of Ministers) in Kyiv. This chapter presents a summary of the pilot project's essential components. More information is included in a paper presented at the 7th International Conference in Geomatics in Ottawa [Palko et al., 1995].

2.1 Hardware and Software

The hardware and software configuration for the Chernobyl GIS pilot project constituted a major component of the technology transfer. Most of it was purchased in Canada and installed in Kyiv, with the exception of a locally supplied PC. The following is a list of the hardware and software components.

Hardware:

- Sun Sparc Station 10, Model 51 with 32 Mbytes RAM and 1.05 Gigabyte Disk;
- 5 Gigabyte Backup Device;
- CD-ROM;
- PC-486 with a Large Digitizing Table (Data Entry Workstation);
- Laser Printer;
- Large Size Pen Plotter.

PC Workstation Software:

- DOS;
- Tydig Digitizing Software;
- Database Management System (SPANS Tables);
- SPANS Map for Data Presentation.

SUN Workstation Software:

- SUN OS 4.1.3 (UNIX);
- MOTIF ICS Version 1.14;
- SPANS GIS Version 5.23;
- Data Translation Software to Interface data from the Local Map (F1) Database.

2.2 Database

The data used for the pilot project originated from two sources: the F1 database and the contamination measurement files. The F1 format is the digital topographic map format of the former USSR. Software was written to extract the relevant information from the F1 database and to convert it into the SPANS import file format. The data derived from the F1 database were classified into eight themes: hydrography, relief, populated places, boundaries, transportation, radiology, man-made objects and vegetation. Each of the data themes contains a number of spatial entities. The entities related to the data themes have not been re-structured from the original data sources. They are a combination of entities defined in the documents obtained from Ukraine.

For example hydrography is composed of the following entities:

bluffs	rapids
canals and ditches	reservoirs
channels	rivers
dams	rivers and channels
dikes and banks	springs
fords	wharves
isobaths	water bodies
lakes	wells
oceans and seas	
ponds	

while contamination samples is composed of the following entities:

air contamination level
cattle contamination level

farm product contamination level
human contamination level
soil contamination level (medical-caesium, strontium, plutonium, potassium, level of exposure)
water contamination level

Hydrography entities were divided into two thematic layers (linear and polygonal features). In order to process lakes into quadtrees, they had to be transferred to SPANS as polygons. Radiology data were imported as point entities and converted to quadtrees for modelling. Each entity was described by spatial and non-spatial attributes as well as by metadata to identify source documents and field collection methods.

3.0 PILOT PROJECT RESULTS

As part of the Chernobyl GIS pilot project implementation, Ukrainian specialists received both theoretical and hands-on training on the installed system. Details of the training are described in a paper presented at the 7th International Conference in Geomatics in Ottawa [Dombrowski, Palko, 1995]. As part of their hands-on training, Ukrainian specialists have developed the following three principal applications:

1) integration of the Digital Chart of the World (DCW) data with local map data;
2) preparation of countermeasure maps, i.e., delineation of zones by density and type of radionuclides;
2) identification of natural landscape zones.

3.1 Integration of the Digital Chart of the World (DCW) Data with Local Map Data

Ukrainian GIS users tested geographic data exchange and data integration, and acquired a readily available map coverage extending beyond their national boundaries. As expected, DCW data proved to be useful for generating overview maps and integrating with local digital topographic map data at small scales. The successful integration of DCW data with local digital data illustrates the benefits of utilizing this data source as a starting point for building a database which could be easily used for small-scale topographic mapping. Figure 1 shows the location of the Polessie District study area and represents an example of the DCW and local data integration. The DCW data is represented by the country boundaries and hydrography data.

3.2 Delineation of Zones by Density and Type of Radionuclides: Countermeasure Maps

The objective of this application was to produce integrated maps (also referred to as countermeasure maps), based on contamination data and other relevant information, for the pilot project area at the scale of 1:200,000 (the smallest de-classified scale). The preparation of these maps tested the methodology of merging existing digital topographic map information (such as base map features, settlements, vegetation and land cover) in F1 format with georeferenced radio nuclide data in Gauss-Krüger coordinate system. This application required the conversion of all the data into SPANS import format. Analysis included interpretation, classification and contouring. The intended use of these maps was for the: identification of the type and level of contamination for populated places and forests; zoning of settlements; and delineation of the exclusion zone under different scenarios. Figure 2 is a sample map showing the caesium-137 contamination for the pilot project study area.

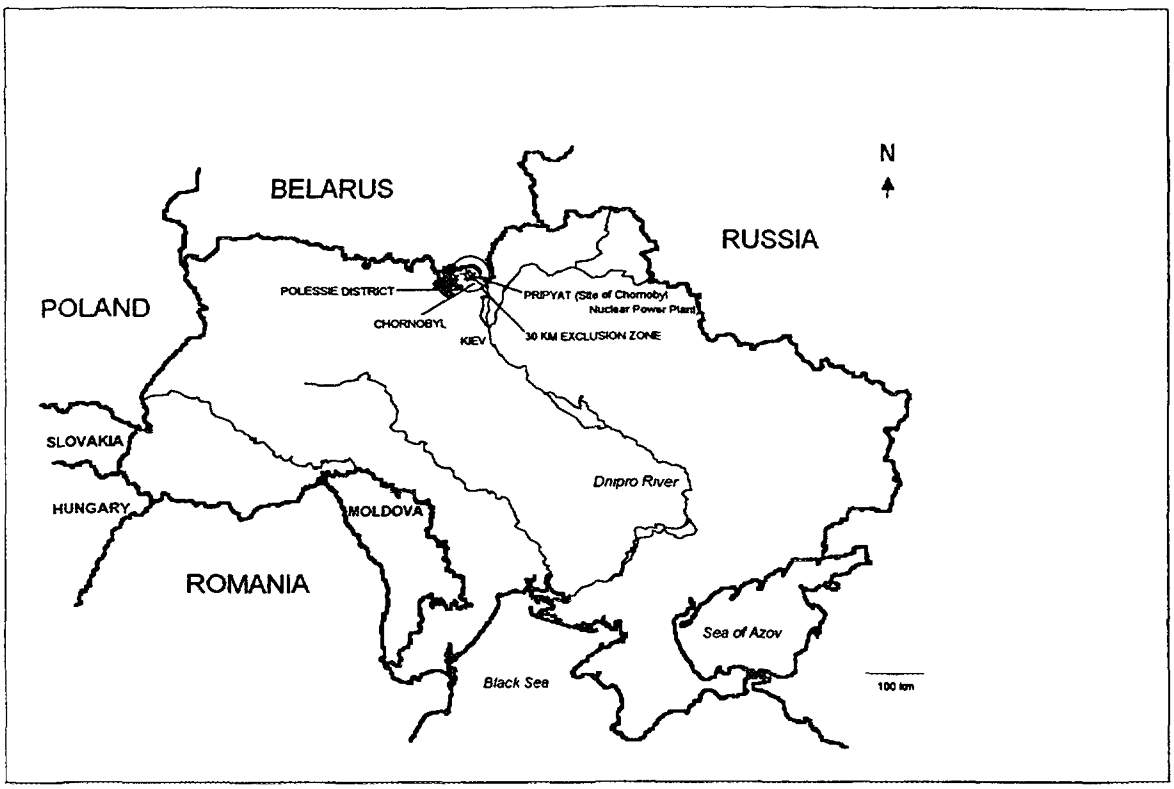

Figure 1: Location of the GIS Pilot Project Study Area

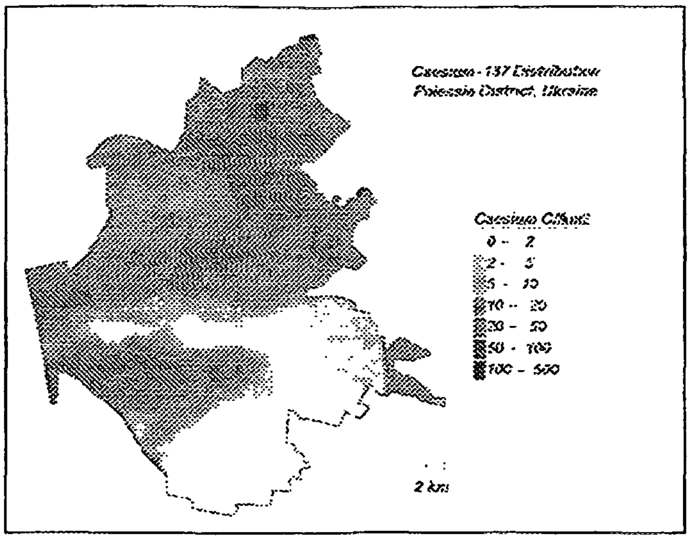

Figure 2: Map of Caesium-137 Contamination in the Polessie District

3.3 Identification of Natural Landscape Zones

The manual delineation of natural landscape zones based on a classification system designed by Ukrainian scientists [Davidchuck, 1994] was replaced and facilitated by the GIS The process involved the integration of data from various scales and sources, calculation of slopes, spatial analysis and overlay of multiple data sets; classification; and presentation of integrated results (e g contamination levels of soil types) Ukrainian scientists considered the natural landscape zones an essential component of countermeasure maps

4.0 CONCLUSIONS

The Chernobyl GIS Pilot Project was successfully completed in December 1994 The project has demonstrated that GIS technology provides sophisticated analysis capabilities that are directly applicable to environmental impact studies of the Chernobyl accident In this context, the project has allowed specialists from Ukraine to gain hands-on experience using GIS as it relates to data integration, data exchange, data modelling and map production The pilot project has provided a better understanding of the existing data types (e.g , paper maps, radionuclide databases), the administrative support available for GIS applications in Ukraine, the collection, input, analysis and output related to the initial applications, and, the production capacity of GIS installed in Kyiv Following the pilot project completion, specialists trained on the system continued to develop innovative GIS applications beyond the objectives and scope established at the onset of the project

The pilot project has identified serious weaknesses in the reliability of existing data (e g , lack of geographic coordinates for point data), clarified which data analyses were realistic, and helped to define follow-up requirements for improved data collection methodologies In addition to GIS technologies, the significance of remote sensing has become apparent during the course of the pilot project implementation Remote sensing imagery would provide important and current map information on vegetation and land cover, monitoring of spring floods and forest fires for modelling applications The credibility of countermeasure maps for the contaminated territories would be enhanced, if prepared using remote sensing images as base maps The pilot project has been successful in meeting most of the objectives identified, as well as in highlighting the requirements to be addressed in follow-up projects.

The authors hope that this pilot project will contribute to a better understanding of the impact of nuclear accidents and, in particular, how the GIS technologies can facilitate the formulation of policies for the rehabilitation of contaminated territories Given the possibility of similar accidents at nuclear facilities elsewhere around the globe, the development of recovery mapping methodologies and policy strategies based on the Chernobyl experience could be invaluable in the future The pilot project is also considered as part of the Canadian contributin to the G-7 initiatives to close the Chernobyl nuclear power plant, and to eliminate environmental consequences of the disaster

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FAR FIELD NUCLEAR FALLOUT EXPERIENCE AND COUNTERMEASURE STRATEGY: A COST-BENEFIT RE-APPRAISAL

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INTRODUCTION

The accident at Chernobyl, near Pripyat in Ukraine, was caused by an explosion in unit 4 of the nuclear power plant. Both the material released and its deposition distribution pattern were much less homogenous than anything released in weapons testing. The near field (up to a few kilometres from the reactor) was heavily contaminated, and part of this contamination was due to fuel particles.

The fire in the plant carried some of the materials to a height of about 1.000-1.500 metres where an air stream carried it first to the western part of the USSR and then on to Sweden and Norway. It was particularly the volatile elements, such as iodine and caesium, which reached the higher levels of the atmosphere and were then transported over great distances (hundreds of kilometres). During the ten days following the accident, when radioactive debris was being released to the atmosphere, the meteorological conditions changed and central and southern parts of Europe also received fallout. Part of this later release was also transported from Central Europe to Southern Norway in May. The fallout in parts of Norway and Sweden was some of the highest outside the former Soviet Union and average levels of ^{137}Cs of up to 200 kBq/m^2 could be found on the ground surface.. It mainly affected rural and mountainous areas with few inhabitants, but which were and are important for production of food. The highest contamination occurred where rain fell during the passage of the radioactive cloud.

FALLOUT AND BEHAVOUR IN FARFIELD

The time of the year (april, may) when the fallout occured, had influence on the consequences. In spring no animals were out grazing and almost no standing crops could receive direct surface contamination. However , uptake and the transfer in the semi-natural ecosystem became considerable important.

In semi-natural ecosystems, soils often have a low mineral content and very little clay and this usually means less findings of the radiocaesium. Even before the Chernobyl accident occurred, it was known that the root uptake of radiocaesium in a semi-natural ecosystem was higher than average in agricultural ecosystems [1].

Undisturbed soils generally have a top layer rich in organic matter and any caesium in this layer is more mobile and generally available for root uptake. However, in tilled agricultural soils, the radiocaesium tends to come into contact with clay particles which have the ability to absorb and irreversibly bind the caesium and greatly reduce its availability for root uptake. Undisturbed soils tend to support plant species which show a relatively high uptake of radiocaesium.

Earlier studies on fallout from nuclear tests had yielded data on the migration and uptake of important radioisotopes under the conditions of almost continuous fallout. Most of these studies concentrated on agricultural systems and with little focus being devoted to food production in semi-natural ecosystems except for the lichen-reindeer part of the food chain. Nevertheless, valuable data on root uptake and long-term behaviour of radiocaesium were obtained. Using these data, it was possible to reassess the results obtained in studies of nuclear weapons tests and to make realistic prognoses about the transfer of radiocaesium and its long-term behaviour after the Chernobyl accident for animals.

Earlier studies had suggested that fallout from Chernobyl would behave differently to fallout from weapons tests. Radioactive substance released under very special conditions could be present in other physico-chemical forms. [2]. A reduced soil-plant transfer of Chernobyl fallout radiocaesium compared to nuclear weapons tests fallout was observed [2] in farfield from the reactor accident. The weapons fallout was readily soluble in water but the Chernobyl fallout was found in a variety of different physico-chemical forms. Close to the Chernobyl site, Loschilov (1991) observed that physico-chemical form of radiocaesium played an important role in determining it's behaviour in the environment. The Chernobyl fallout radiocaesium deposited in Norway was to a minor extent found as fuel particles, mostly in the forms of colloids and simple cations [3] [4]

However, despite the fact that the Chernobyl caesium deposited in Norway was found in a variety of physico-chemical forms, it has been shown that radiocaesium from Chernobyl and radiocaesium from weapons fallout behaved very similarly with respect to distribution and migration in soil and uptake by plant and animals [5] [6]. This is true at least after the first initial phase after the fallout. The long term behaviour of radiocaesium in the environment is also very similar for the two fallouts [5] [6].

Radiocaesium was the most important radionuclide for dose to man from both types of fallout, and consumption of contaminated food is an important source of dose [7][8][9][10].
Result from experimental fields showed no significant difference in the soil-to-plant transfer of the two types of fallout .
It was shown by Oughton (1989) that both types of fallout were in equilibrium with the stable caesium in the soil and despite the fact that deposition of the fallout occurred 20 years apart

the transfer factors were almost identical . These measurements were made on a highly organic soil containing very little clay.

The effective ecological half life can be long (up to 30 years) for many of the plants and food stuffs produced in the semi-natural ecosystem [5] .
The long ecological half life may be due to several factors. Assessments made in the wake of the Chernobyl accident showed that the ecological half-life of ruminants grazing semi-natural ecosystems had not been properly addressed [5]. It was not generally known that effective ecological half-life could be that long, especially if fungi were present for the grazing animals (I,II).

In semi-natural ecosystems, root uptake is the rate-determining step and therefore also governs the intake by grazing animals. The main exception to this is the lichen-reindeer pathway where surface contamination of the lichens is largely responsible for the activity levels of radiocaesium in reindeer in winter when lichens are the main source of food for reindeer. In winter, the ecological half-life for weapons fallout and Chernobyl fallout in reindeer showed no significant difference: the half-life being 3 - 4 years in both cases (table) . This again demonstrate the similarity in behaviour of radiocaesium from nuclear weapons and from Chernobyl.

COUNTERMEASURES

In order to minimise the harmful effects of radiation arising from fallout it may be beneficial to implement countermeasures and thus reduce the dose to man. Clearly it is essential to administer such countermeasures so as to derive the maximum benefit.
This means evaluating the effectiveness of the countermeasures in terms of practicability, monetary cost, social cost etc. etc. Other important considerations are when to apply the countermeasures and for what length of time the countermeasures should be called for. To do this it is essential to understand and predict the long-term behaviour of the more important radioisotopes.

There is generally a good agreement on the basic radiological protection philosophy regarding the introduction of countermeasures following an accident [11]. It is agreed that countermeasures should be justified and optimised and should result in a net benefit to man, i.e. they must do more good than harm.

Agricultural countermeasures studies were first conducted some 40 years ago largely as a safeguard against possible contamination of land through fallout from nuclear weapons. The countermeasures studiy was aimed mainly at combating contamination of crops, fodder and animals by Sr, Cs and I.

Generally, the implementation and effectiveness of countermeasures will depend on many different factors. Some of the most important are time of year when fallout occurred (seasonality), site-specific factors, type of agriculture products, the physico-chemical form of the fallout etc. However, just as important, are also economic, psychologic and social consequences to be considered.

Fallout on the ground and urban constructions such as buildings and roads can be an important source of external radiation to man. A considerable reduction in potential dose can be achieved through carefully planned decontamination procedures or, in the extreme, by evacuation or relocation. Such countermeasures were not used in Norway following the Chernobyl accident but they were judged to be unnecessary and used in the former USSR. Countermeasures for external radiation will not be discussed further in this document but some appropriate studies on this subject have been reported [12] [13].

In the event of a nuclear release, countermeasures against inhalation of radioactive materials may be called for. Such countermeasures would of necessity be short term. Appropriate countermeasures would be remaining indoors, wearing gas mask and taking of potassium iodate tablets to reduce uptake of radioiodine by the thyroid gland. In Norway, after the Chernobyl accident, no countermeasures were used to reduce the dose from inhalation.

A variety of techniques are available for minimising mans intake of radioactivity from contaminated food. Any proposed countermeasure should take into account factors such as effectiveness, practicability, cost and social consequences. Many normal agricultural practices are effective in minimising uptake for newly contaminated land. Often agricultural countermeasures are connected to:

1) Reducing uptake from soil to plants by use of fertilisers, ploughing or changing the land use.
2) Reducing the transfer from plants to animals by the use of food additives.
3) Increasing the rate of excretion from the animal.
4) Processing of contaminated crops to yield a less contaminated product.

Limiting consumption of contaminated food, abandoning land and moving people from contaminated areas are obvious methods for reducing potential radiation dose. Ploughing and the addition of fertilisers are normal agricultural practices which can also be effective in reducing dose. Where meat producing animals are contaminated through grazing contaminated pastures, contamination in meat can be greatly reduced by using clean pastures of forage for just a few weeks before slaughtering (special feeding).

The implementation of countermeasures will have implications in terms of cost to society. Such cost has to be compared with the corresponding reduction in health risk. The Chernobyl accident presented an opportunity to evaluate the cost-benefit of various countermeasures. The effect of different countermeasures may be estimated from experiments and experience after implementation in Norway following the Chernobyl accident. The cost of the countermeasures were estimated from available accounts and budgets in connection with implementation and compensation regulations. Information of the scale of the contribution and the effect of the countermeasures make it possible to estimate the averted dose. The findings compiled will be the basic for performing an simple cost benefit analyses.

COUNTERMEASURES AND COST-BENEFIT ANALYSIS

However, no plans for countermeasures existed at the time of the accident, so they had to be improvised. Due to research and developments some countermeasures, e.g. interdiction were replaced by more convenient and cost-effective methods.
Six types of countermeasures were used in Norway to reduce radiation doses following the Chernobyl accident. They were interdiction of food, special feeding, fertilisation of natural pasture, the use of caesium binders, changing diet and changing slaughtering time of reindeer. Countermeasures considered, but not implemented, were the relocation of animals to uncontaminated areas and restriction of some agricultural production in contaminated areas. Table shows the result of cost benefit analyses performed on countermeasures implemented in Norway after the Chernobyl accident.

Table

Cost of countermeasures in terms of manSv saved.

Countermeasure	NOK/manSv
Interdiction sheep	1000 000
Interdiction reindeer	340 000
Special feeding	250 000
Change of slaughter time	94 000
Prussian blue boli	4 000
Prussian blue concentrate	1 000
Dietary Advices	40

From a radiation protection point of view it was correct to implement countermeasures in Norway after the Chernobyl accident. The countermeasures implemented reduced the doses, and therefore are expected to reduce the health risk [14]. In retrospect, the countermeasures taken have been proved to be cost-effective. However, in optimizing countermeasures it is necessary to consider more than cost in monetary terms and averted dose.

JUSTIFICATION OF IMPLEMENTING COUNTERMEASURES

Almost all countermeasures used in Norway were justified. The cost of their implementation was less than the possible cost inflicted on the society had the potential dose not been reduced (III,table 6, [14]).

The value of countermeasures can be calculated as the monetary cost of averting radiation dose (in units of manSv). It is assumed in this extent that the relationship between dose and effect is linear. The society's willingness to save a statistical life can be expressed by an a-value. This willingness is compared with other risks faced by society. Currently, in the Nordic countries a value of 100,000 $ per manSv is recommended [15]. Countermeasures with a cost of averted dose below this value are justifiable, and this was the fact for almost every countermeasure used after the Chernobyl accident ((III,Table 6). However, the result showed that effect and cost-effectiveness of the implemented countermeasures varied considerable (III, table 6). This together with social and political considerations had to be taken into account in establishing the strategy for mitigating the consequences of the Chernobyl accident.

The countermeasures applied in Norway were mainly in line with those described in the literature [16] but some new were also developed (IV).
Crick (1992) showed the importance of cost-benefit analysis in decision-making regarding the implementation of countermeasures in the contaminated agricultural environment. In the wake of the Chernobyl accident, cost-benefit analyses on the use of caesium-binders in Norway came out favourably (more cost-effective) compared with some countermeasures taken in the former USSR [17]. The estimated optimum level estimated for the use of caesium binders for dairy cattle was found to be 40 and 8,000 Bq/kg in the former USSR (Crick 1992). This is in the same range in which the countermeasures were applied in Norway (III).

OPTIMIZING

The cost-effectiveness of different countermeasures varied considerable (III, table 6) but it was necessary to use countermeasures in combination even if some countermeasures were more cost-effective than others. In an optimizing process the aim is to use the most cost-effective of the justifiable countermeasures. This may indicate that one should focus on using the most cost-effective of the available countermeasures (e.g. the dietary advices) before the use of the less cost-effective once (e.g. special-feeding). However, the cost per unit averted dose for the different countermeasures is not showing the total cost. The total negative consequences of the Chernobyl accident and use of countermeasures are also dependent on the economic losses from reduced sales of agricultural products due to fear of radiation (III). Immediately after the accident the situation is not clear and there was insufficient knowledge about the fallout pattern. In Norway, as in several other European countries, the Health Authorities introduced intervention levels for radiocaesium contamination of food. There were little room for optimizing the situation. Later a clearer radiological protection philosophy was introduced. Clearly some countermeasures will have advantages in being practicable and leading to the greatest reduction in dose at minimum cost. This would be the input for a simple cost-benefit analysis but social and psychological factors must also be included in an overall strategy (III), [14]. Overall, the objective of a countermeasure programme is to reduce the dose to the population while minimising economic and psycho-social consequences.

After the Chernobyl accident, the countermeasures applied were carefully monitored and a more or less optimum situation was achieved (III). In retrospect, it was shown that most of the countermeasures employed were justified (III). For people to be confident that the food they are purchasing carries no or very small health risk is an important point when considering the social cost to society. To have basic food products below the intervention levels is, together with information about health risk, probably one of the major factors in establishing trust among consumers. It is also important that basic food bought in shops should not require the consumers to take any special precautions. Thus it is necessary to compare more than just costs and averted dose.

A decrease in the sale of some agricultural products represented a potential economic loss considerable higher than the cost of implemented countermeasures (III). Not all the countermeasures would have the desired effect of satisfying the consumers. The intervention levels were especially important in this respect. This gave some limited use of dietary advices and the need for countermeasures working in the agricultural production system e.g special feeding and caesium binders. Dietary advices were given to critical groups (VI,VII,VIII) and permitted higher national intervention levels for certain foodstuffs.

The use of only dietary advices alone instead of also special feeding would perhaps have given the same averted dose at a lower cost. However the special feeding program led to activity levels in food below the invention levels (III) and no active involvement by the consumers was called for (III,IV). The combination of the different countermeasures took this into consideration and probably gave the maximum reduction of the total negative consequences.

A decrease in consumption of some of the most affected foods (e.g. lamb) occurred. The decrease in consumption of lamb was about 5 to 10 % in the first years (III). This represented a loss of about NOK 50 to 100 mill. On the other hand, if no countermeasures except interdiction had been taken and the intervention was maintained, the cost would have been about 100 to 400 mill NOK each year (III). Without countermeasures, lost sales of lamb could have been considerable and for several NOK 100 mill.

From the discussion above one may conclude that measures taken to protect the population from radiation dosed and health consequences of the Chernobyl accident where relative extensive and resource demanding III, [14]. Their main intent was to reduce the physical health effects by reducing radiation dose. The dose was reduced and the relationship between cost and reduced dose was acceptable and below the value recommended (III). They may also have had beneficial effect on physcological and social health of many people, although firm evidence does not exist. The countermeasures implemented also had a beneficial effect on costs to the agricultural community since international derived intervention level were implemented. Without the implementation of countermeasures the agricultural community would probably have suffered much greater losses through a fall in sales of the more sensitive foods (e.g lamb and reindeer meat).

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XA9745820

MODELLING OF RADIONUCLIDE TRANSPORT IN FORESTS: REVIEW AND FUTURE PERSPECTIVES

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1. INTRODUCTION

Ecological modeling is a powerful tool which can be used to synthesize information on the dynamic processes which occur in ecosystems (1). Models of radionuclide transport in forests were first constructed in the mid-1960's, when the consequences of global fallout from nuclear weapons tests and waste disposal in the environment were of great concern. Such models were developed based on site-specific experimental data and were designed to address local needs (2-4). These models had a limited applicability in evaluating distinct ecosystems and deposition scenarios. Given the scarcity of information, the same experimental data sets were often used both for model calibration and validation, an approach which clearly constitutes a methodological error. Even though the early modeling attempts were far from being faultless, they established a useful conceptual approach in that they tried to capture general processes in ecosystems and thus had a holistic nature. Later, radioecological modeling attempted to reveal ecosystem properties by separating the component parts from the whole system, as an approach to simplification. This method worked well for radionuclide transport in agricultural ecosystems, in which the biogeochemistry of radionuclide cycling is relatively well understood and can be influenced by fertilization. Several models have been successfully developed and applied to human dose evaluation and emergency response to contaminating events in agricultural lands (5-7).

2. RECENT FOREST ECOSYSTEM MODELS FOR RADIONUCLIDES

The Chernobyl accident provided valuable information for calibration and validation of models where the lack of a major synthesis of usable information was clearly demonstrated(8). Developments in techniques for sampling and analysis and recent computer software improvements have allowed radioecologists to implement integrated field and modeling programs in which ecosystems of interest can be partitioned both experimentally and conceptually, and empirical fluxes of radionuclide contaminants determined. However, attempts at incorporating these parameters have sometimes led to increasing complexity of the models. In addition, many of the parameters needed in the models are difficult to measure and the experimental values have a wide range, and therefore a large uncertainty. For example, in an attempt to reduce uncertainty in soil-to-plant transfer factors for radionuclides, a working group of the International Union of Radioecologists defined standard conditions for field measurements (9). The resulting values for agricultural crops, however, still have uncertainties of some two orders of magnitude. Forest ecosystems are much more complex and are likely to have even greater ranges of values. This large variability complicates the use of transfer factors in forest ecosystems. Documentation shows that natural ecosystems have even higher parameter uncertainties than agricultural ecosystems due to site variability, the layered structure of soils and diversity of plant cover. It is not surprising that attempts to apply the complex models developed for agricultural ecosystems to natural environments have not been very fruitful.

At least five recently developed models ECORAD (10), FORESTLIFE (11), RIFE (12) Biotic model (13) and FORESTPATH (14) have been used in fitting sample data collected from the Chernobyl zone and then deriving factors for the inter-compartment transfer of radionuclides, (Figure 1). This approach provides site-specific information which can be used in further general model development. An interesting finding in comparing a forested region only 7 km from the Chernobyl reactor with a forest area in Ireland shows that ^{137}Cs is much more mobile in the soil in Ireland than adjacent to Chernobyl (15). A possible explanation is that the initial deposition near Chernobyl was low-solubility "hot" particles and the Irish fallout was soluble and thus more readily available for root uptake. In using these data for predictive model development, transfer factors between compartments and the use of advection and diffusion coefficients in the soil layers have been discussed. Coefficients defining transport of ^{137}Cs through the upper soil layers have been deduced from such measurements (16). A problem faced by forest modelers is the complex dynamics in the system and the time dependent variability in the transfer of radionuclides. This large variability complicates the use of transfer factors in forest ecosystems. A model for radionuclide cycling in vegetation and uptake by animals relates the primary production, growth and turnover of ^{137}Cs (13). This model focuses on the biotic system, in contrast to other models which are generally driven by transport in soil (16).

Another useful approach employs a spread sheet to define parameters and to make probabilistic calculations on the time distribution of radionuclides in the forest compartments as well as radiation doses received by man as a result of a wide variety of exposure pathways (17). This screening model, FORM, has limited applicability in that it is specifically designed to assist in the development of criteria for clean-up of contaminated forests. It begins to address the many technical and economic issues in a comprehensive approach which includes use of forest products, dose to workers, cost/benefit analysis and management options. One major value of this approach is that it provides a useful package in which appropriate parameter values are compiled and synthesized for use by the non-specialist.

3. A GENERIC MODEL - FORESTPATH

In this paper, we advocate a holistic approach to radioecological modeling. However, forest ecosystems are so complex that it is impossible to separate many of the interacting components and processes controlling radionuclide transfers and storages. Our current knowledge of forest radioecology requires development of generic models to be used as tools to synthesize the available information and to guide future experimental programs. The FORESTPATH model describes the major kinetic processes and pathways of radionuclide migration in forests and natural ecosystems (Figure 1). The model can be used to predict future radionuclide concentrations by calculating the time-dependent radionuclide concentrations in different compartments of the forest ecosystem based on the information available on residence half-times in two forest types: coniferous and deciduous (14,18). Results of model simulations in Figure 2 show that forests can efficiently accumulate the radioactivity released to the environment and that the understory, tree and organic layer are the major sink compartments contributing to human radiation dose. The FORESTPATH model reproduces well the radionuclide cycling pattern found in the literature for deciduous and coniferous forests. This model also provides a method for evaluating human and ecological radiation doses. The model simulations can be used for quantitative evaluation of the effectiveness of different remedial actions. As a demonstration of its practical usefulness, it has already been applied to guide a comprehensive sampling program in the forests contaminated by the Chernobyl NPP accident (19). The results of the measurements are shown in Figure 3.

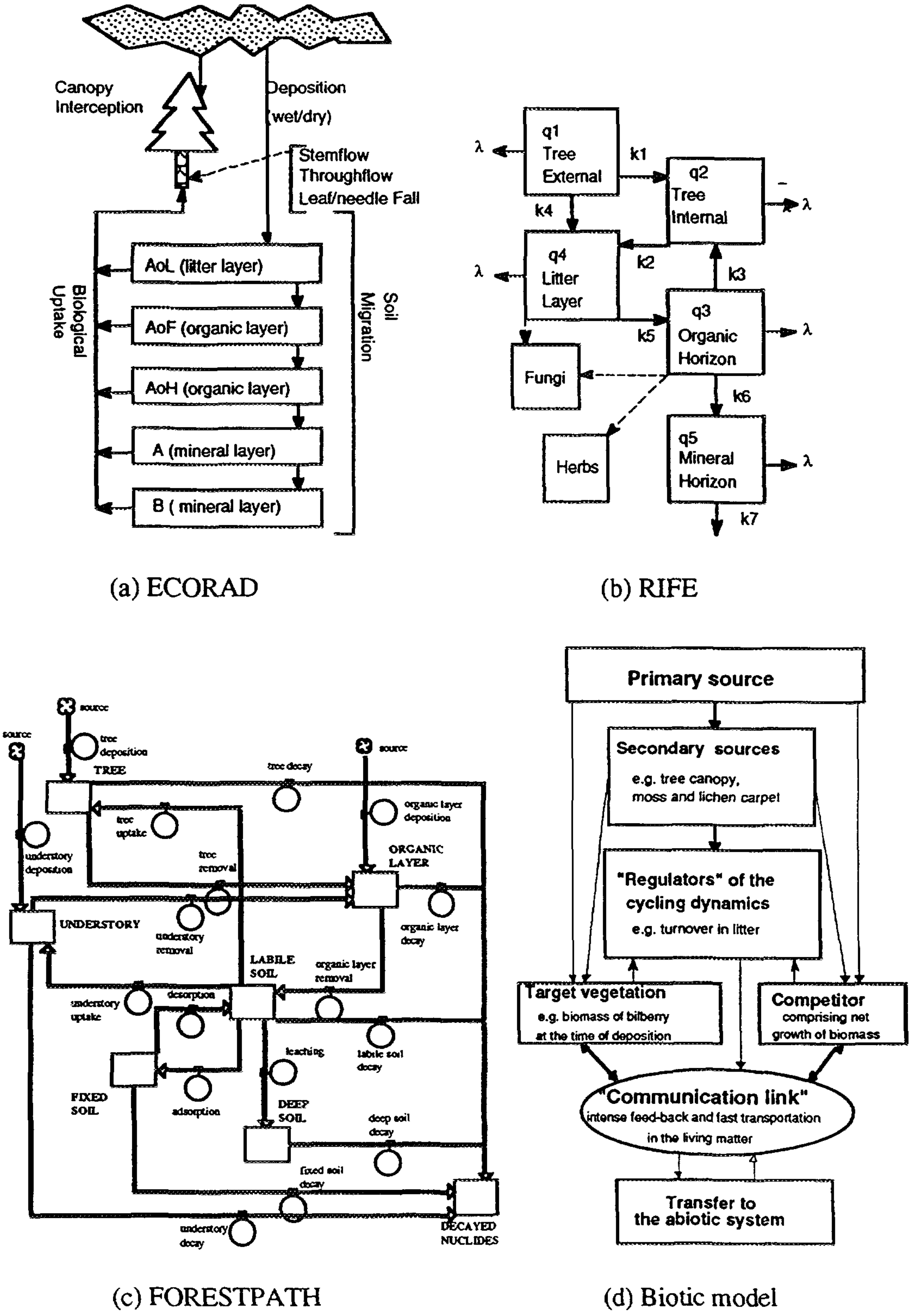

Figure 1. Framework for modeling radionuclide behavior in forest ecosystems:
a) ECORAD, b) RIFE, c) FORESTPATH, d) Biotic model.

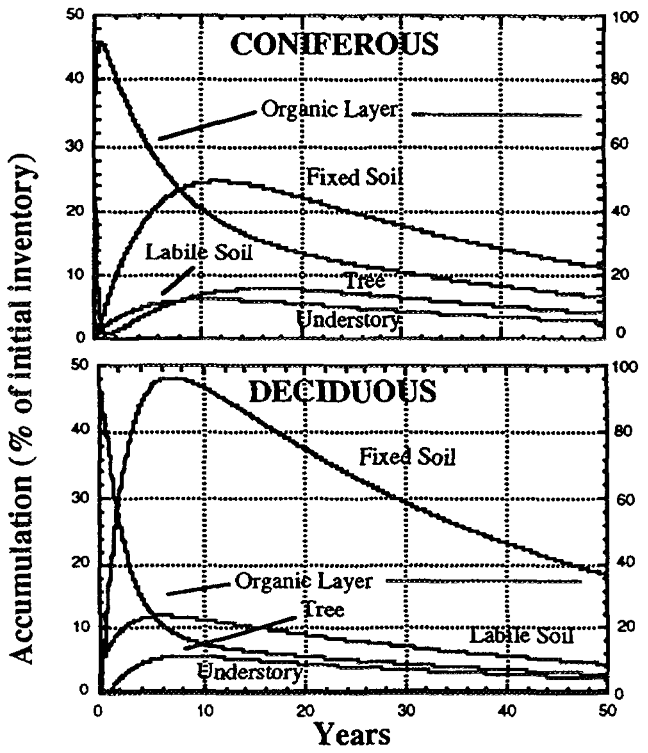

Figure 2. Results of generic model runs for predicting ^{137}Cs distribution in forests using FORESTPATH.

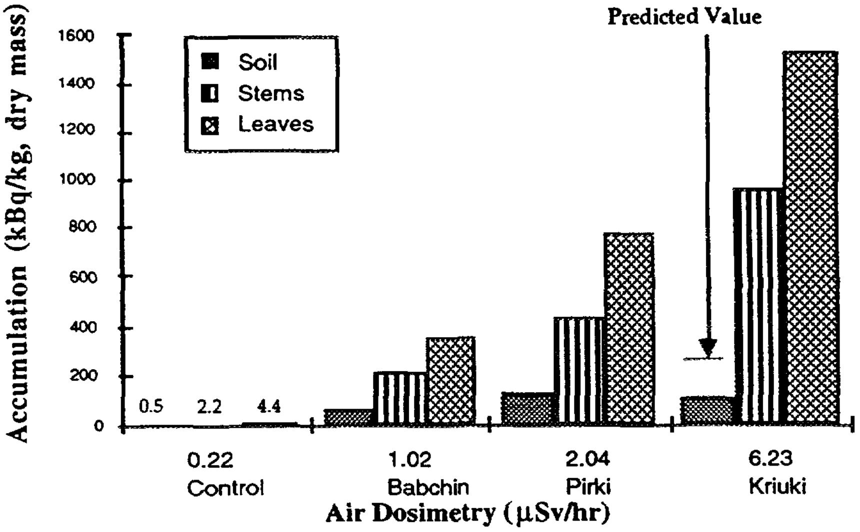

Figure 3. Accumulation of ^{137}Cs by fern in Chernobyl area coniferous forests, July 1994, at sites with different dosimetric levels 1m above the soil. Samples measured by M. Gerzabek, F. Strebl and V. Karg, Austrian Research Center, Seibersdorf.

4. CONCLUSIONS

Future model development requires accurate definition of key components of the generic forest ecosystem, while taking into consideration the interactions with neighboring interface ecosystems such as aquifers, catchment basins, marshlands, and rivers. These conceptual models can be tested using data from the literature. If coherence is found between these tests and site specific information, then the model has credibility and further information is required to validate it. The validation process is undertaken to identify the most important variables which control the output predictions, i.e., sensitivity analysis. If these variables are not known within reasonable error limits, then a field sampling and analysis program should be undertaken. The final approach to the model is to use one ecosystem where the model functions well and then use independent information from another ecosystem which is located in a different area. After adjusting for such features as soil types, organic layer, biomass distribution, temperature, species, etc., a validated model should be able to predict radionuclide concentrations over a time period following contamination. After the basic dynamic predictions are validated, then the model can be used to evaluate other social, economic, political, dose reconstruction, and site remediation activities which may be considered in the aftermath of a nuclear contamination event. The process of modeling radionuclide behavior in natural ecosystems is progressing slowly but with strong implications for both ecology and for risk identification and assessment purposes. However, for semi-natural ecosystems, we still cannot confidently answer the question: When once contaminated by radionuclides, how long will it take to restore a contaminated zone into productive use by the affected population?

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CONTAMINATION AND RADIATION EXPOSURE IN GERMANY FOLLOWING THE ACCIDENT AT THE CHERNOBYL NUCLEAR POWER PLANT

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1. RADIOACTIVE CONTAMINATION [1]

The radioactive substances released following the accident at the Chernobyl nuclear power plant were distributed by atmospheric transport over large parts of Europe. Due to dry and wet deposition processes, soil and plants were contaminated.

1.1. Activity concentrations in air

The "radioactive cloud" was first monitored on the 29th of April by near surface measurement stations; by the 30th of April the whole of southern Germany was affected. The contaminated air then spread out in both westerly and northerly directions, resulting in increased airborne radioactivity over the entire country within the following days.

1.2. Ground contamination

Airborne radionuclides were deposited on soil and plants in dry form as well as by precipitation. Locally varying depositions resulted from different activity concentrations in aerosols and very large differences in the intensity of precipitation during the passage of contaminated air masses. Rain falls were particularly heavy in Germany during the time the cloud was passing, especially south of the Danube, where on average 2,000 to 50,000 Bq of Cs-137 was deposited per square meter on soil, and in some cases even as much as 100,000 Bq per square meter. Fig. 1 illustrates Cs-137 ground contamination in the year 1986.

1.3. Local dose rate

As a consequence of the contamination of air and ground from fallout, an increase in dose rate was observed. The local dose rate and its change through time were essentially determined by the conditions as described in Section 1.2. This behaviour was particularly pronounced in the south-eastern and southern part of Germany.

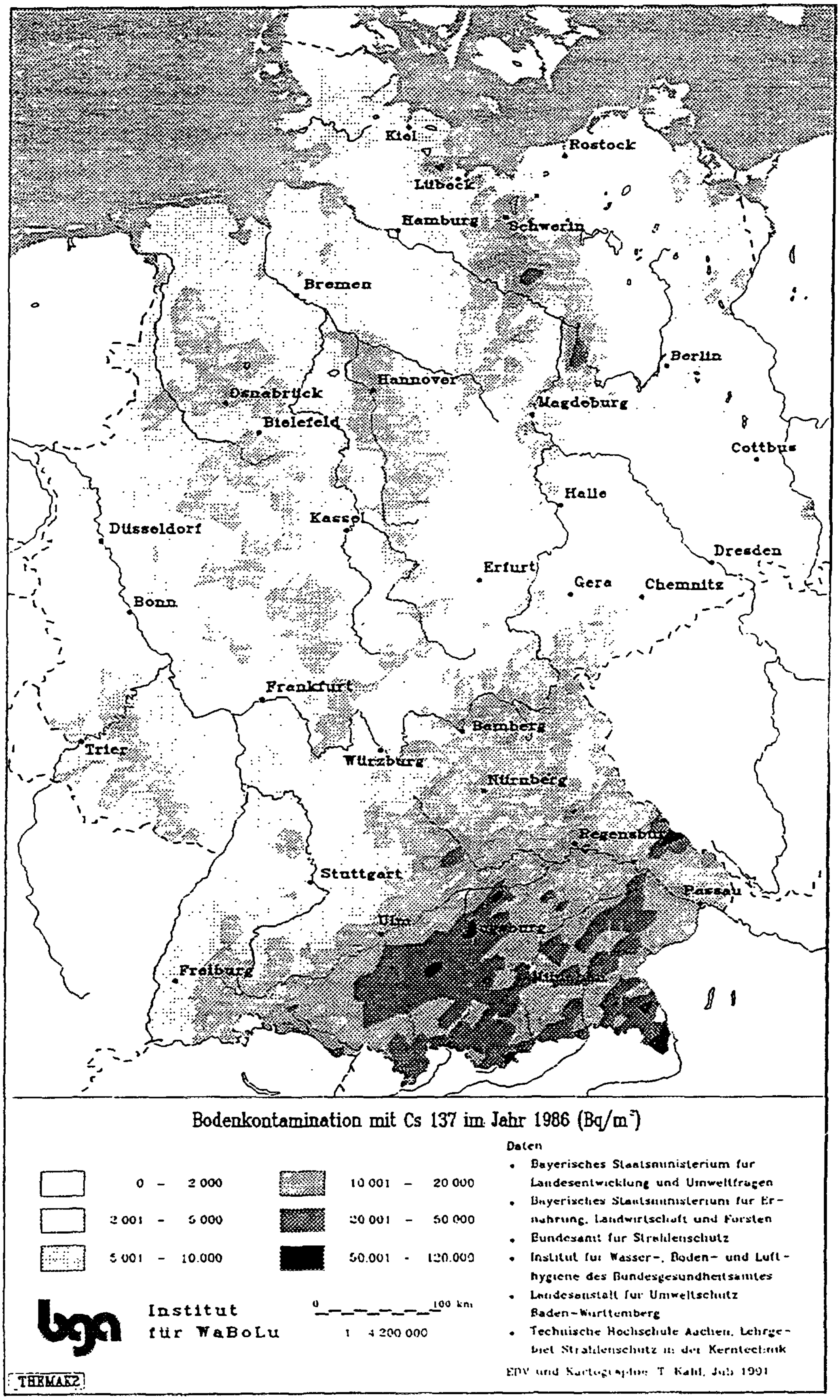

Fig 1. Ground Contamination of Cs-137 in 1986

1.4. Activity concentrations in drinking water

The contamination of drinking water by airborne radioactive substances depends primarily on the contamination of untreated rainwater used for producing drinking water. With the exception of cistern water where, depending on the dilution volume, radionuclide concentrations were measured up to the concentrations in precipitation, the mean values for all radionuclides in all other untreated water sources were below 1 Bq/l.

1.5. Specific activity in foods

Products ready for harvest in May, such as lettuce, spinach and pasture plants, showed a relatively high contamination from direct radionuclide deposition. After the I-131 specific activity had markedly decreased and caesium isotopes were still of significance, the contamination of other foodstuffs gained in importance.

Figures 2a to 2b illustrate the change of activity concentrations over time in milk. These figures show that, shortly after the radioactive cloud arrived, comparatively high I-131-activity was already measurable in milk from cows that had grazed on contaminated pastures. By the end of May, however, I-131 had almost completely disappeared from milk. Radiocaesium-activity reached a maximum approximately one month after contamination, slowly decreasing thereafter. In winter, when contaminated hay was fed to the cows, the activity was again enhanced and remained fairly constant until the next grazing season began.

Only specific pathways, such as game and mushrooms, are still of interest 10 years following the accident In various mushroom types, more than 1000 Bq/kg of Cs-137 can still be measured in southern Bavaria. Blueberries, blackberries and wild strawberries may still be contaminated with Cs-137 at about 300 Bq/kg. Similar, high activity concentrations may also occur in game if the animals graze mainly in forest and not in agricultural areas.

2. RADIATION EXPOSURE OF THE POPULATION [2]

The contamination of air, soil, water and foods by radionuclides over various exposure pathways has led to an additional radiation exposure of the population.

2.1. Exposure from radionuclides in the air

Exposure from radionuclides in the air occurred only during the passing of the "cloud" and are considered to be insignificant in comparison to the exposure from radionuclides deposited on the ground.

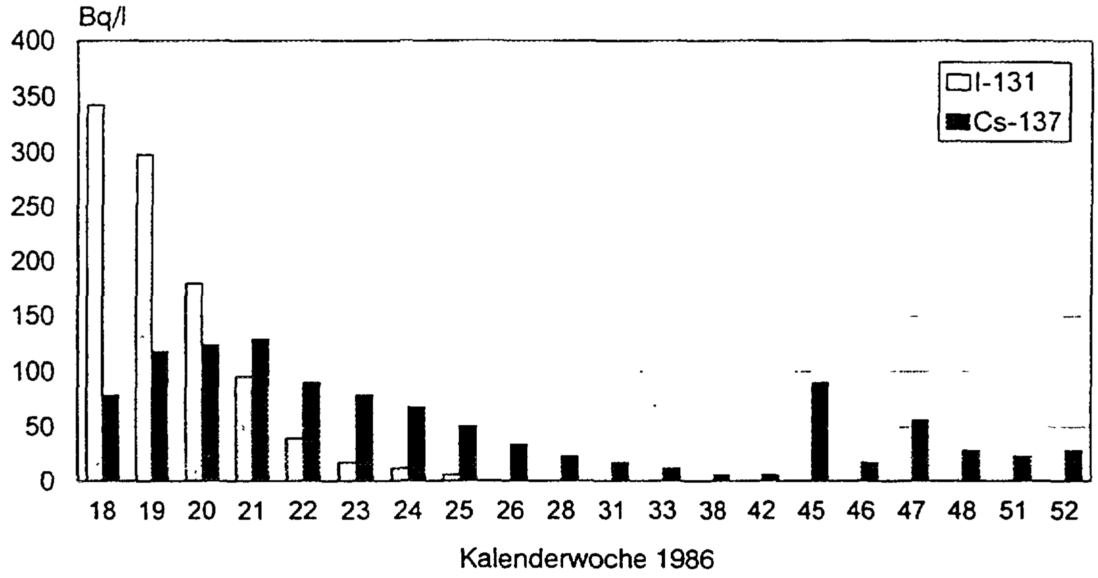

Fig 2a. Mean specific activity of I-131 and Cs-137 in milk (South Bavaria) in 1986

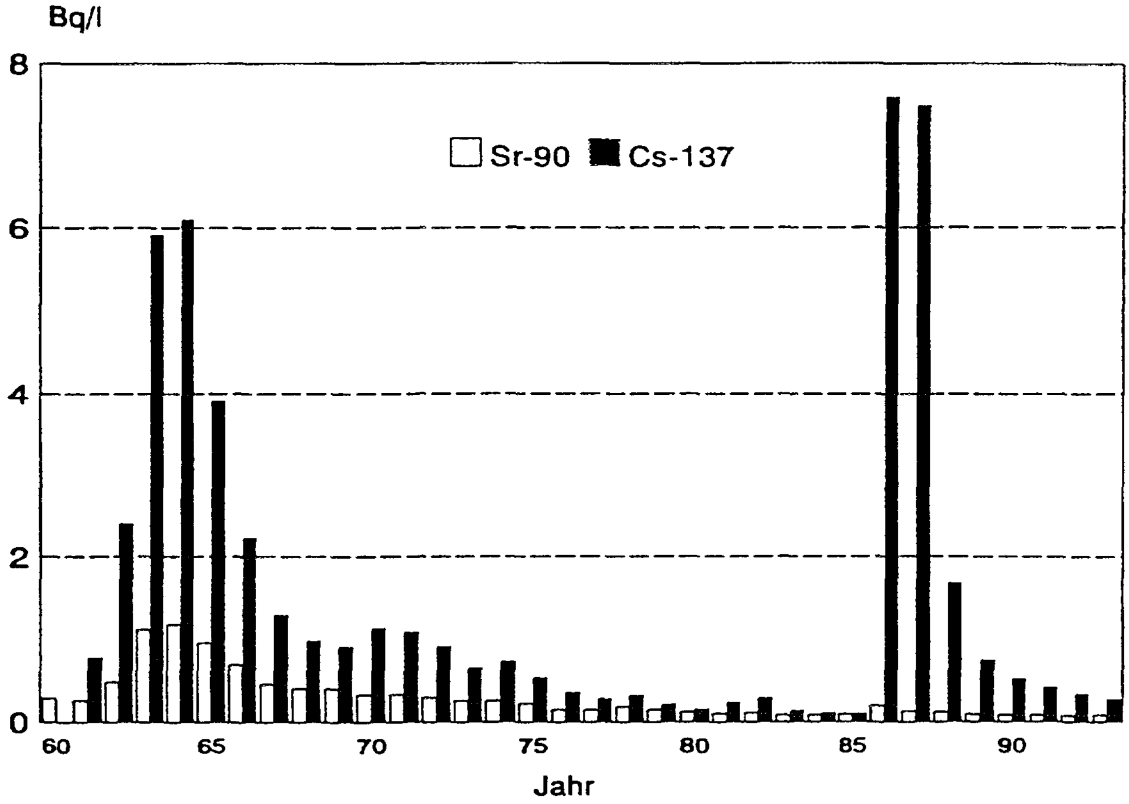

Fig 2b. Mean specific activity of Sr-90 and Cs-137 in milk (Germany)

2.2. Exposure from radionuclides deposited on the ground

For estimating the exposure from radionuclides deposited on the ground, such influential factors as the place and length of residence, shielding, wash-off from buildings and concrete ground surfaces as well as the migration of radionuclides into deeper layers of soil must be considered. As shown in Table Ia, exposure estimates performed by the SSK (Commission on Radiological Protection) have led to the compilation of values for typical contaminated areas

2.3. Exposure due to the inhalation of contaminated air

Exposure from the inhalation of contaminated air did not contribute significantly to the overall effective dose. Inhalation doses, as estimated by the SSK for the area south of the Danube, are shown in Table Ib Values north of the Danube are a factor of 2 to 10 lower than those shown in Table Ib and are up to a factor of 2 higher in the pre-alpine area

2.4. Exposure due to the ingestion of contaminated foods

Exposure estimates of ingested amounts of contaminated foods are accompanied by uncertainties. For example, the origin of foods bought, and thus the amount of their contamination, is often unknown to the consumer. Similarly, individual eating habits may have changed. In a representative inquiry, taken in May 1986, about two thirds of those questioned had changed their eating habits with regard to fresh vegetables and lettuce, possibly resulting in reduced dose

Exposure of the population from the ingestion of radionuclides in foods was determined by whole body measurements performed on reference groups and the internal dose accumulated since 1986 was calculated from these measurements In the population of southern Germany (as calculated from

TABLE Ia. CUMULATIVE EFFECTIVE DOSE BY EXTERNAL IRRADIATION [2]

area	"representative Cs-137-contamination" (Bq/m_)	cumulative external radiation exposure (mSv) infant 1 year	5 years	lifetime	adult 1 year	5 years	lifetime
pre-alpine region	32 000	0.3	0.6	1.5	0.2	0.5	1.3
south of the Danube	16 000	0.15	0.3	0.8	0.1	0.25	0.7
north of the Danube	4 000	0.04	0.08	0.2	0.03	0.07	0.2

TABLE Ib. DOSE DUE TO INHALATION (SOUTH OF THE DANUBE) [2]

Inhalation doses	infant	adult
effective dose (in mSv)	0.03 - 0.07	0.02 - 0.04
thyroid dose (in mSv)	0.45 - 1.2	0.35 - 0.7

TABLE Ic. MEAN EFFECTIVE DOSE DUE TO INGESTION [2]

area	mean effective dose due to ingestion (mSv)	
	1 year	lifetime
pre-alpine region	0.25	0.6
south of the Danube	0.15	0.4
north of the Danube	0.08	0.2

representative measurements taken in the Munich area) the internal dose early in 1996 amounted to about 0.12 mSv for women and to about 0.18 mSv for men.

SSK estimates (Table Ic) contain mean values for the first post-accident year as well as over the entire lifetime for men, women and children in the pre-alpine area and regions south and north of the Danube. In addition to ceasium-137, other radionuclides deposited are also included. However, owing to dietary habits, 80% of values deviate from mean values by more than a factor of 3.

2.5. Total exposure

According to SSK estimates, persons who were infants at the time of the accident received a total mean effective dose within the 12 months following the accident via the various pathways of 0.17 mSv (north of the Danube), 0.35 mSv (south of the Danube), and 0.65 mSv (prealpine region).

3. COMPARISON OF EXPOSURES TO NATURAL RADIATION [1]

The sum of external and internal exposures from natural radioactive substances results in a mean value of about 2.4 mSv/yr in Germany (Fig.3), although this value varies between 1 and 10 mSv per year. During the course of a lifetime (70 years), this type of exposure would accordingly result in an effective lifetime dose between 70 and 700 mSv.

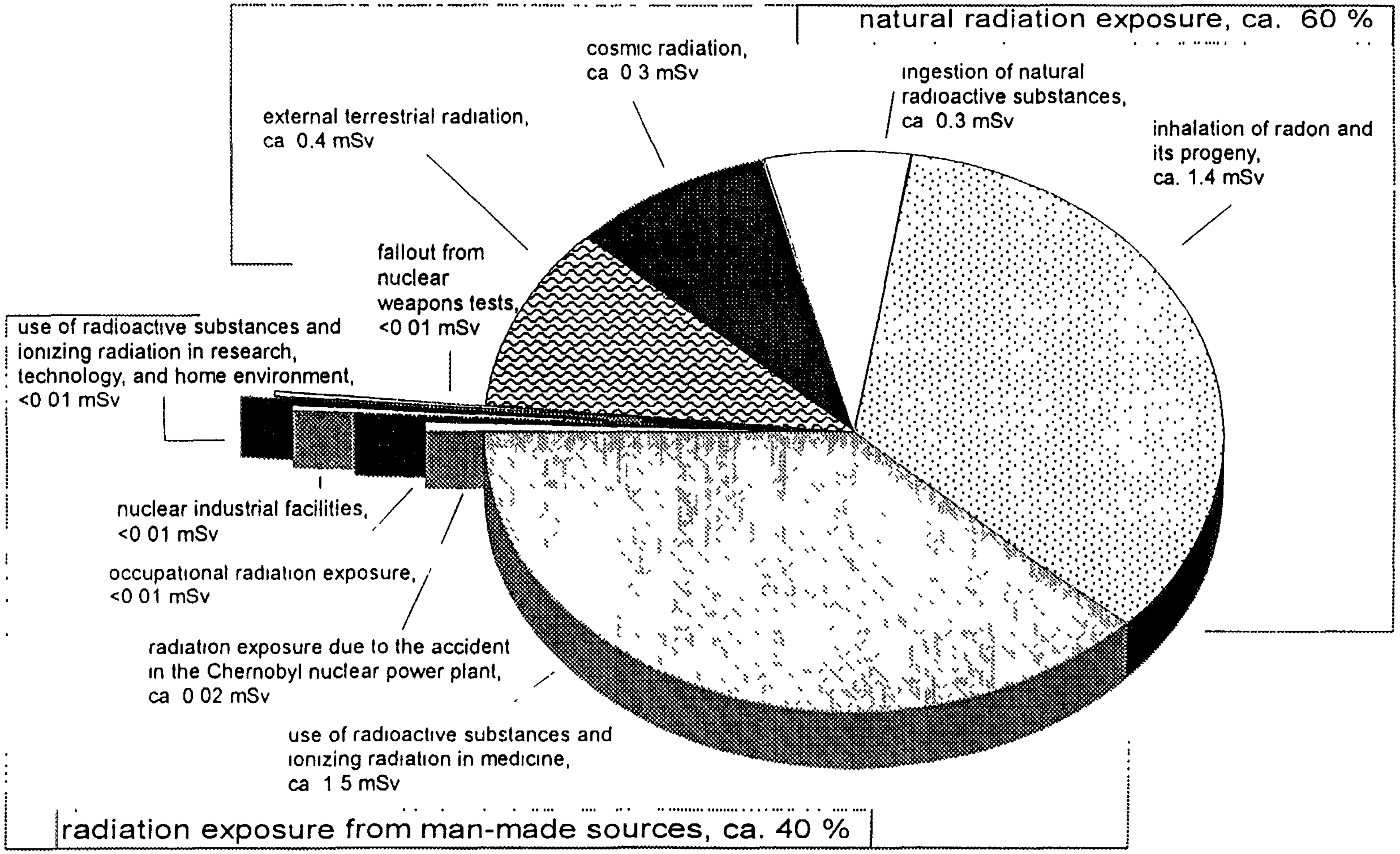

Fig 3. Contributions to the mean effective dose of the population of Germany in 1993

As compared to the values estimated in Chapter 3, it follows that the additional mean effective dose of 0.35 mSv during the first post-accidental year for children living south of the Danube corresponds to about 15% of the mean annual dose caused by natural radiation sources. In some pre-alpine regions, the values are about twice as high. The total mean dose during the 50 years following the reactor accident to this same group of persons (estimated at about 1.3 mSv) corresponds to about 1% of the mean dose from natural radiation sources over an entire lifetime. Here, again, dose values may be twice as high in some pre-alpine areas.

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RADIOECOLOGY OF THE VARDAR RIVER CATCHMENT AREA AFTER THE CHERNOBYL RELEASE

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1. INTRODUCTION

Vardar river with its length of 301.6 km and its catchment area of 28,338 km^2 covers almost 80% of the territory of the Republic of Macedonia. Various usage of the surface and underground water flows of this hydro system (water supply, irrigation, etc.) to which gravitate cca 2/3 of the population of our Country, are subject of increased interest for their protection. In this sense, radioecological investigations (due to a presence of a local not well prospected uranium deposits and a factory for phosphate fertilisers) were in progress[1].

Immediately, after the first information for the Chernobyl disaster from the 26th of April, 1986, as a result of the accident at the Chernobyl Nuclear Power Plant, and the registered increased level of radioactive contamination of the environment of our Country, our research work as well as the activity in the Republical Institute for Occupational Hygiene and in the Institute for Veterinary, both, also from Skopje, have been intensified. As a result of unusual high amount of precipitation, in May 1986, the contamination of the whole country was expected to be increased, and this fact was confirmed later on. According to this, appropriate recomendations and activities to the population were suggested, as well as adequate protective measures have been taken.

The fi.st preliminary results of performed gamma-spectrometric analysis showed that besides many others, the following isotopes: I-131, I-132, Cs-134, Cs-137 and Ru-103, dominated into the investigated water, air and food samples[2]. Different from the concentration of I-131 into the filtered Skopje air which was 12 Bq/m^3 on the 5th of May, 1986, the concentration of Cs-137 was up to 15 Bq/m^3 in air, 122 Bq/L in local precipitation, up to 800 Bq/kg in sediments and 0.29 Bq/L in the water samples from the Vardar river.

During the realization of the planned investigations, following the Chernobyl accident, which were more or less systematic, valuable data for the distribution of individual isotopes within the Vardar river system , determining the level of radioactive contamination of different water, food, soil and other samples, have been collected.

On the basis of the obtained results, calculations for the Chernobyl disaster contribution to the effective equivalent dose for adults for the year 1986 and 1989-1992 period were performed.

Financial support was provided by the Fund for Science and Technology of the Republic of Macedonia

2. RESULTS AND DISCUSSION

As a result of unusual high amount of precipitation, in May 1986 in some regions even more than 100 L/m^2, the radioactive contamination of the whole country caused by the Chernobyl disaster, was increased. The concentration of I-131 and Cs-137 in various samples of milk during May, 1986, was in the range of 100-5000 Bq/L and 100-500 Bq/L, respectively.

Certain results received by the performed systematic radioecological investigations, related with the determination of the distribution of various observed radionuclides in different environmental samples, for the period following the Chernobyl disaster, as average concentrations for the covered period are presented in Table I and Fig.1.

TABLE I. DISTRIBUTION OF CERTAIN OBSERVED RADIONUCLIDES IN VARIOUS SAMPLES FROM THE CENTRAL PART OF THE VARDAR RIVER CATCHMENT AREA

Investigated sample	Period Month/year	Average conc.	of observed	radionuclides	in Bq/kg or L
		Ru-103	Cs-134	Cs-137	I-131
	May/'86	120+-14	70+-11	220+-16	84+-12
	Dec/'86	/	69+-9	166+-11	/
Uncultivated soil	'87	/	76+-10	131+-11	/
	'89	/	/	40+-5	/
	'90	/	/	10+-3	/
	'91	/	/	15+-3	/
	May/'86	174+-16	120+-20	221+-26	271+-8
Grasse	'87	$<10^{-2}$	19+-2	38+-3	$<10^{-2}$
	'89	/	/	20+-2	/
	'91	/	/	12+-2	/
	May/'86	125+-17	122+-6	133+-8	197+-20
Milk	'89	/	/	<1	/
	'90	/	/	<1	/
	'91	/	/	<1	/
	May/'86	602+-28	859+-38	1634+-45	254+-22
	April/'87	$<10^{-1}$	68+-18	155+-31	$<10^{-1}$
Wheat	Aug/'88	$<10^{-2}$	163+-20	373+-40	$<10^{-2}$
	'89	/	/	14,6+-1,5	/
	'90	/	/	8,6+-1,0	/
	'91	/	/	4,0+-0,5	/
	May/'86	327+-16	657+-14	1540+-38	498+-21
Lamb's meat	'89	/	/	10,0+-1,0	/
	'90	/	/	7,0+-1,0	/
	'91	/	/	3,7+-0,5	/

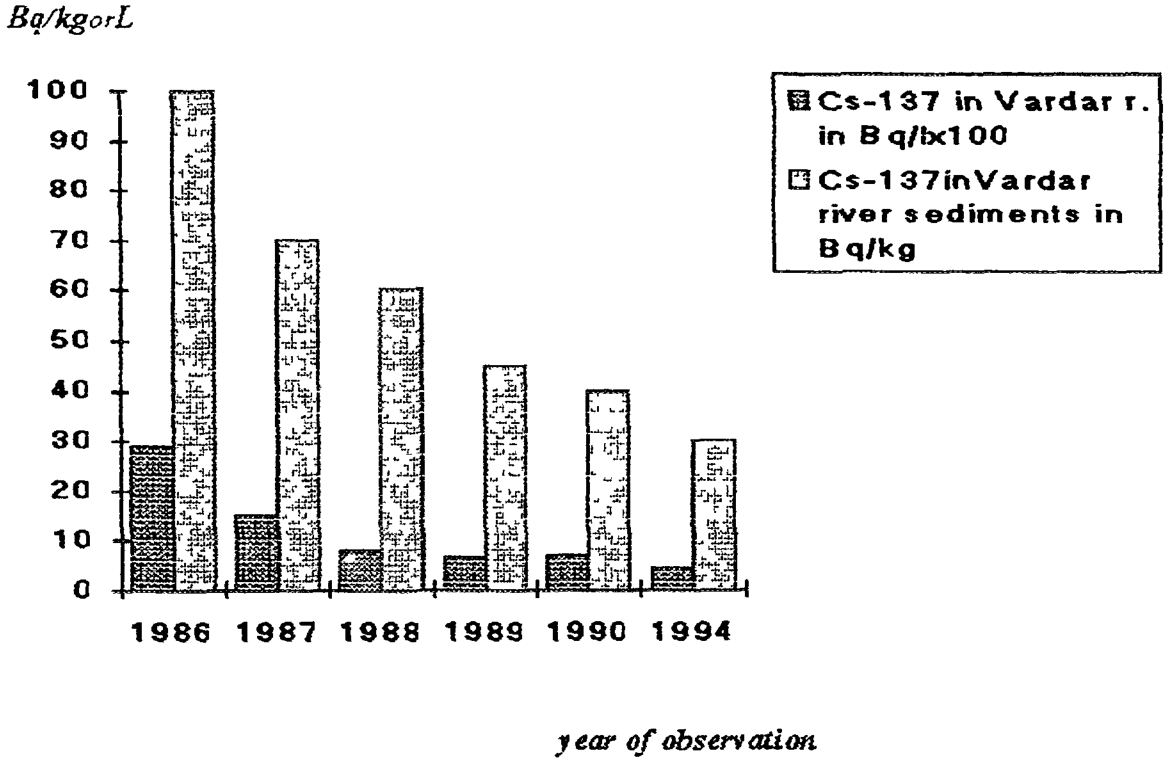

FIG 1. *Cs-137 concentration in sediments and water samples from the Vardar river in Bq/kg or L for the period after the Chernobyl disaster*

It is evident, that in the beginning the spectrum of the registered radionuclides was larger. I-131 and Ru-103 were between the first radioisotopes which disappeared within the few months after the accident.

As, by the end of 1986, Cs-137 was (due to its long half life) the dominant isotope into the investigated environmental samples within the Vardar river hydro system, in our further research work we pay to it a special attention.

At present, as it can be seen from the Fig. 1, the concentration of Cs-137 in the water and sediment samples from the Vardar river are reduced to 0.045 Bq/L and 30 Bq/kg, respectively

Although, many other radionuclides migrate slowly into soil profile depths and as rule they are located in a soil layer with thickness up to 10 cm, the presence of Cs-137 in concentration range 30-60 Bq/kg in first 20 cm of uncultivated and 40 cm of cultivated soil sampels is registered up to present days. This is in agreement with the experience, that the more distant from the Chernobyl Nuclear Power Plant, the greater is the share of mobile forms of Caesium in soils, recived by the scientists in the Republic of Belarus[3] Thus, the radionuclides penetrated into the soil and involved in the migration processes will be present in the biological chain "soil-plant-animal-man" for a long time

3. MODELLING

On the basis of the results obtained by the performed radioecological investigations of the Vardar river system and taking into the consideration many other relevant parameters, calculations for determination of the Chernobyl disaster contribution to the effective equivalent dose for adults for the year 1986 and 1989-1992 period, were done and respective values of 1.50 and 0.02 mSv/y were received.

By using of adequate mathematical model[4-7], evaluation of the effective equivalent dose to be received by the local population , due to the possible usage of contaminated river water for both, irrigation and for water supply, was performed and values in good agreement with the previous, obtained on the basis of the field measurements, were received.

4. CONCLUSIONS

Apart from the obtained results throughout the performed radioecological investigations, in the period after the Chernobyl accident from one side and the applied technique of data evaluation, from the other, the following conclusions can be drown,

- Period after the Chernobyl disaster, i.e. after the 26 of May '86, was characterized with an increased level of environmental radioactive contamination of our country. According to the radioactivity level in different samples and locality, appropriate recomendations and measures have been taken.
- Correlation between the radioactivity of soil and grasse sampes, from one side and these in milk and meat samples, from the other, is evident, enabling us to use it successfully in evaluation the prediction of the efective equivalent dose to be received with time, by the local population.
- Applied model for the evaluation of the effective equivalent dose for the local population , to be received due to the possible usage of river vater for both, irrigation and water supply, showed good agreement with the calculations based on the field measurements.
- The contribution of Chernobyl disaster to the effective equivalent dose to the local population, at present days is very low, approaching the contamination level before the accident.

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RADIOACTIVE WASTE MANAGEMENT ISSUES RELATED TO THE CONVERSION OF THE CHERNOBYL SARCOPHAGUS INTO AN ECOLOGICALLY SAFE SYSTEM

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1. INTRODUCTION

The importance of the issue and the scale of the problem of accident-derived radioactive waste management after the Chernobyl disaster have been recognized internationally [1, 2, 3]. Ten years after the accident this issue remains dominant in the remedial actions, and it acquires a new significance with regard to the solution of the problem of sarcophagus. This structure was built around the remains of the destroyed nuclear reactor Unit 4 immediately after the accident, in order to control radioactive releases to the environment and to ensure nuclear and radiation safety during the sarcophagus lifetime. Its main components are a vast concrete shelter encasing the crippled reactor building and security systems, including a monitoring system, a system for injection of neutron absorbing material into the damaged reactor and a system for dust sedimentation in the central reactor hall. Due to these measures radionuclide emissions have been kept within permissible limits and other monitored parameters were properly controlled. However, there is a growing concern about the sarcophagus stability and the assurance of continued nuclear and radiation safety [4].

The sarcophagus currently suffers from the extreme conditions in which it was hastily built, it may not last for 30 years, as was intended, and it may collapse earlier. Another cause of concern is the interaction of fuel-containing masses with water percolating into the shelter, possibly leading to migration and accumulation of fissile materials which, in turn, may result in reaching the state of criticality. The consistency of nuclear fuel debris is changing with time, and the monitoring and safety systems are deteriorating. With the increasing uncertainties of the data acquired, the confidence of any prediction is very low. The collapse of the sarcophagus would lead to a new radioactive contamination of the territory, groundwater and rivers. Thus, its conversion into an ecologically safe system is a pressing problem. The Gordian knot of the problem is to maintain safe management of a huge amount of messy radioactive waste both inside and outside the sarcophagus. The purpose of this paper is to discuss the issue in the light of the prospects for conversion of the sarcophagus and related activities currently being undertaken or planned in Ukraine.

2. ACCIDENT-DERIVED RADIOACTIVE WASTE MANAGEMENT

As it is now well known, the largest long term consequences of the accident at the Chernobyl NPP are wide-spread contamination of the territory and a huge amount of radioactive waste arising from the process of environmental restoration. The following numbers demonstrate the scale [5]: more than 100 000 km^2 of territory is contaminated with ^{137}Cs at > 1 Ci km^{-2} (37 kBq m^{-2}), 28 000 km^2 at >5 Ci km^{-2} (185 kBq m^{-2}) and above 10 000 km^2 at > 15 Ci km^{-2} (555 kBq m^{-2}). Thousands of square kilometres of the territory are also contaminated with ^{90}Sr and about a 1000 km^2 with $^{239+240}Pu$ at > 1 Ci km^{-2} (37 kBq m^{-2}) and > 0.1 Ci km^{-2} (3.7 kBq m^{-2}), respectively. In some smaller areas, such as the flood plain of the river Pripyat, the contamination of ^{90}Sr, for example, reaches 100-1000 Ci km^{-2} (3700 - 37 000 kBq m^{-2}). In Ukraine alone the radioactive contamination affected more than 2000 towns, villages and hamlets.

Immediately after the accident, the most highly radioactive waste (fragments of the roof of the reactor building, fuel and graphite debris, etc.) was placed back into the destroyed reactor building (later enclosed into the sarcophagus) and into a nearby open pit excavation at the farmstead Podlesny, which was modified for waste storage. Some of the most highly contaminated soil and rubble (a mixture of high, intermediate and low level radioactive waste) went into the excavation of the fifth unit of the Chernobyl NPP, located 1.5 km away, which was also reconstructed as a waste storage facility, now known as Complexny. Each of these two facilities, Podlesny and Complexny, occupies an area of 0.5 ha and initially contained up to 2×10^{16} Bq of total activity. The amounts of this waste are 5×10^3 m^3 and 1.5×10^4 m^3, respectively.

One ongoing problem is that a significant amount of smaller but highly radioactive fragments of the blown up reactor core that were spread around the destroyed building, might have been buried outside the sarcophagus under the protective concrete layer on the ground [6]. There is no available knowledge about them to date but there is an urgent need to study and to acquire this information.

Large volumes of less radioactive soil and other similarly contaminated material from the NPP site and from other areas, both close to and more remote from the site, were disposed of in shallow pits and trenches. In total, about 800 of them were dug at 25 locations adjacent to the NPP in order to accommodate the urgent needs for a storage place for the waste. These pits and trenches could not be designed in such a way as to provide a long term containment of the radionuclides and therefore may need to be relocated to a final repository. This would be a very difficult task, since in total the disposal pits and trenches occupy an area of several hundreds of hectares and contain a volume of material of about 4×10^6 m^3. The disposed waste is estimated to contain 10^{15} Bq of ^{137}Cs and probably an equal amount of ^{90}Sr and about 10^{13} Bq of $^{239+240}Pu$. At present the waste is being disposed of in the first organized near surface disposal facility within the 30 km zone, near the former village of Buryakovka.

Considerable research has been carried out to study the migration of radionuclides in geological media in the 30 km zone and around the disposal sites, some of which, for example, Oil Tank Farm, Sandy Plateau, Yanov Station, Red Forest, were found to have contaminated or to have a certain potential for contaminating groundwaters and the river Pripyat. However, the results of the studies are fragmental and the general picture is still far from being complete. Therefore, this is an important area for further studies.

Some generic problems have also been encountered in the management of radioactive waste after the Chernobyl accident. One of them relates to the absence of international guidance on radiological cleanup criteria, and the other to the classification and characterization of the accident-derived waste which is extremely heterogeneous in terms of both activity and composition. These problems cause difficulties in assessing what portion of the contaminated material should be considered radioactive waste and, also, in properly planning and organizing the process of safe and efficient management of waste.

3. THE CURRENT STATE OF THE SARCOPHAGUS AND THE PROSPECTS FOR ITS CONVERSION

The sarcophagus is one of many, although it is the largest radioactive waste storage facility resulting from the Chernobyl accident. It constitutes a potentially severe nuclear and radiation hazard. The area encompasses seismic activities with the estimated frequency of an earthquake of magnitude 6 on the Richter Scale about once every 100 years. There is also some concern about the possible effects of bad weather, since the sarcophagus has many slits and openings of various kinds amounting to 1000-1400 m^2. Both earthquakes and storms could cause damage to the sarcophagus and a release of radioactive dust, and thus, recontaminate the environment. The threat of this is enhanced in view of uncertainties as to the physical state of the sarcophagus. Some of the structures, in particular, the upper plate of the reactor biological shield, with a weight of more than 2000t, and some of the internal supports for the sarcophagus are in unstable, poor or unknown condition. It is evident that should these structures fail, the radioactive dust would be released.

This situation requires an urgent conversion of the sarcophagus into an ecologically safe system. In view of the complexity of the task for this purpose in 1992 the Ukrainian government organized an international competition. The competition demonstrated that in proposed projects and technical solutions, approaches to the management of radioactive waste confined to the sarcophagus, as a final objective, were a measure for projects adequacy and maturity. Technically, and in the view of reaching the final objective, a phased approach to the conversion of the sarcophagus into an ecologically safe system received a major support during the international competition and recent feasibility studies by Alliance, a consortium comprising a group of finalists of the competition. (The consortium consists of leading European organizations, Campenon Bernard, AEA Technology, Bouygues, SGN, Taywood Engineering, Walter-Bau and of a number of Ukrainian and Russian organizations and institutions).

The phased approach, as proposed by Alliance [7], includes stabilizing of the original sarcophagus and building a new structure, followed by processing of radioactive waste, final dismantling of all structures and disposal. A period of 10 years would be necessary to build a new shelter which would both provide a containment for protecting the environment from uncontrolled releases of radioactive materials and function as a dismantling complex for the safe retrieval of radioactive waste contained in the sarcophagus during the next 20 - 25 years. It is envisaged that short lived low level and intermediate level waste would be disposed of in near surface repositories within the 30 km exclusion zone. The concept for isolation of high level and alpha bearing waste in Ukraine is to dispose of this waste in deep geological formations, most probably of the Ukrainian Shield. A great effort is required to come to this last phase, including development and implementation of special kinds of waste segregation, minimization and other waste treatment technologies and a great deal of international co-operation.

4. SARCOPHAGUS WASTE

The status of knowledge concerning the radioactive waste inside the sarcophagus is briefly as follows [4]. The total activity in materials is about (4-7) x 10^{17} Bq. During the accident the reactor core was completely destroyed. Spent nuclear fuel from the core was scattered inside the building in a variety of ways and forms. Fragments of fuel assemblies thrown from the reactor are scattered in the central hall and other rooms with a small portion remaining in the reactor pit. Other major forms are lava which formed in the accident and cooled rapidly into a vitreous mass, and radioactive dust particles. The lava contains about ten weight percent fuel on average, and its rate of degradation is notably fast. Surface reactions, attributed to oxidation, water penetration and radiolysis, are occurring several orders of magnitude faster than anticipated. Finely dispersed high active fuel and graphite dust can be found to cover the surfaces and in the form of aerosol in all the rooms. This means that a large amount of building materials have been contaminated inside the sarcophagus resulting in radioactive waste of various types and activities.

The quantitative assessment of radioactive waste inside the sarcophagus is a difficult task, since part of the radioactive materials are not accessible for direct observation and measurement. Summary estimations of possible waste arisings are given below.

According to the estimation of the Interdisciplinary Scientific and Technical Center "Shelter" of the National Academy of Sciences (NAS) of Ukraine the amounts of materials in the sarcophagus conditionally classified as high (above 3700 MBq/kg), intermediate (3.7 - 3700 MBq/kg) and low (0.74 - 3.7 MBq/kg) level waste are following. High level waste: spent nuclear fuel assemblies - 60t, fragments of fuel assemblies - 10-36t, material in vitreous form - 192 m^3, fuel dust - 7-10t, reactor graphite - 320 m^3, building materials - 6000 m^3, metal constructions - 21500t. Intermediate level waste includes 186000 m^3 of contaminated building materials, 22700t of metal constructions and about

3000 m^3 of radioactive (10^6 - 10^9 Bq l^{-1}) water. The last group, low level waste, includes 66000 m^3 of building materials and 2860t of metal constructions.

Estimation of waste arisings expected during the dismantling of the sarcophagus, made by Alliance, gives the volume of short lived waste over 500,000 m^3, and of long lived and high level waste - about 40,000 m^3. This is compared with over 300,000m^3 of radioactive waste arisings before and during the construction of the new shelter. About 100,000 m^3 of this waste is expected to be classified as "exempt" waste and the major part of the remaining waste would be classified as short lived waste.

5. RADIOACTIVE WASTE MANAGEMENT STRATEGIES AND PRIORITIES

Though some important strategy points have been outlined in Section 3 above, a consistently developed strategy for dealing with sarcophagus waste and a general national radioactive waste management policy in Ukraine have not yet been developed. The latter is in the process of being developed in harmony with the IAEA RADWASS fundamental principles [8] and international radioactive waste management standards and recommendations [9, 10]. A hindrance to progress is that the accident-derived waste management constitutes an intervention, for which there are no international criteria. Although some recommendations for intervention are contained in the International Basic Radiation Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [11], which apply to the Ukrainian situation, these recommendations are of very general nature. For their implementation, more specific requirements and guidance need to be developed, taking into account both the benefits and the overall costs in particular national circumstances.

Thus, for Ukraine, the development of policy and strategies, which would embrace the management of the radioactive waste arising in different practices and interventions, is now a high priority task. There is a great need for help in fulfilling this task and in drafting regulations and standards. Some assistance is expected from the IAEA and EC through the Agency's technical co-operation programme and the EC CONCERT (Concertation of European regulators) Group. There should be a close co-ordination of the Alliance project and these activities.

Should the Alliance project be implemented, considering the projected timescales of 30-35 years and potentially 100 years, the waste management facilities and approaches to the retrieval and processing sarcophagus waste will continue to change as the projects develops. However, the strategy today should be based on the design incorporating technologies which are either proven by experience or qualified by testing or analysis.

It goes without saying that before beginning any construction activities the site must be cleaned up in order to work in safe conditions. Therefore, a high priority practical task is to collect all data necessary for safety assessment and site cleanup activities. In particular, the appropriate data on the contamination levels of the soil and the groundwater around the sarcophagus have to be acquired. The waste arising from the cleanup operations will require some form of treatment and storage facilities. But because of the large volume of waste arisings, it should be short term storage and the ultimate disposal routes for low level and short lived waste should be determined prior to the start of the cleanup operations. Development of a geological repository for disposal of high level and long lived radioactive waste is also an important element of the strategy and a high priority task.

For a number of reasons (environmental, economical and socio-political) the 30 km exclusion zone of the Chernobyl NPP is being considered as the most appropriate area for disposal of waste arising both within and outside this zone. Data on geological, geomorphological and hydrogeological conditions, as well as the experience in operating Buryakovka disposal facility, generally support this approach [4]. One of the more favourable areas for further detailed studies within the 30 km zone is located on the watershed of the rivers Uzh, Ilya, Sakhan and Pripyat. Geomorphologically it represents a hilly moraine elevation with expected geological and hydrogeological characteristics suitable for siting a near-surface repository for low and intermediate level short lived waste.

The existing data on deep geological and hydrogeological conditions are scarce and generally not favourable for siting a geological repository with the 30 km zone. There are, however, geological formations in the areas immediately beyond the boundaries of the 30 km zone and in more distant areas of Ukraine which are potentially suitable for developing a geological repository. The examples are: the Lower Proterozoic syenites of the Korostenskiy intrusive system and the andesite porphyrites of the Ovruchskaya series in the north-western part of the Ukrainian Shield adjoining the exclusion zone. Studies conducted at the area survey stage have shown that the eastern part of the Korostenskiy pluton, close to the town of Polesskoe, has a good prospect for the location of a geological disposal facility.

Investigations performed in the above mentioned part of the Korostenskiy pluton by the Ukrainian State Committee on Geology and Utilization of Mineral Resources and by a number of institutes of NAS have made it possible to identify areas with potentially suitable sites for a geological repository and to plan activities for the site characterization stage. These include geophysical investigations and drilling boreholes to a depth of 1.2-1.5km to obtain evidence on actual geological structure, hydrogeological, geochemical, physico-mechanical, thermo-physical and other properties of rock masses.

Despite difficult economic situation, Ukraine has allocated and continues to spend enormous financial resources on rehabilitation of the environment and on the protection of the affected people in accordance with the "Ukrainian National Plan to Mitigate the Effects of the Chernobyl Catastrophe". In the last 3 years, the expenditure was within 5 - 7 percent of the annual national budget. About 70% of the mitigation budget in the past were allocated, however, to compensation and resettlement. A large amount of money has also been spent to meet the requirements for safe operation of the remaining units of the Chernobyl NPP, which is an important source of the country's energy supply. However, understanding the world public concern about continuing operation of this power plant, Ukraine has made a political decision to shut down the NPP units by the year 2000. Taking due account of the complexity of the situation, the necessity to ensure the safety requirements and of interdependencies of all stages, decommissioning of the plant shall follow the Preparatory Action Plan based on the general policy which includes stabilization of the energy supply system, management of spent nuclear fuel and radioactive waste and solution of the sarcophagus problem.

It is necessary to realize that the Preparatory Action Plan, though relatively small compared to international standards, involves an enormous burden on Ukrainian economy, featured by both an energy crisis and an unbalanced commodity production system. Therefore, Ukraine is unable to fulfil the plan on its own, but rather must obtain assistance from the world community.

To provide an adequate scientific and technical support for the implementation of the above Action Plan, the Government of Ukraine has initiated establishing an International Scientific and Technological Centre for Nuclear and Radiation Accidents Problems which would also be in the interest of all mankind. The Centre would provide necessary conditions for creating an effective system of consecutive studies and analysis of all consequences of the Chernobyl accident, including further research on decommissioning of the NPP, conversion of the sarcophagus into an ecologically safe system, management of radioactive waste and health consequences. This last issue was particularly emphasized during the WHO International Conference on the Health Consequences of the Chernobyl and other Radiological Accidents (Geneva, 20-23 November 1995): "The WHO would want to see the volume and quality of medical assistance and scientific research increased. We shall be doing a disservice if we shall fail to extract benefits for mankind out of this monumental human tragedy. If history is not to repeat itself we should learn very well the lessons of Chernobyl" [12].

6. CONCLUSIONS

The best accepted environmental approach to solving the Chernobyl sarcophagus problem comprises as major activities cleanup of the site, stabilization of the existing shelter and building a new shelter (to protect the environment from uncontrolled radioactive releases and to be used as a plant for retrieval of waste from the sarcophagus), eventual dismantling of all structures and the satisfactory disposal of radioactive waste.

All of these activities have to be carried out as an integral part of the Ukrainian National Plan dealing with the post-accident situation and Preparatory Action Plan for plant decommissioning. In particular, close co-ordination has to be provided with the efforts on environmental restoration and remediation of waste sites in the vicinities of the NPP, management of radioactive waste arising from other operating NPPs and planned early decommissioning of all units of the Chernobyl NPP. Finally, a great deal of effort will be necessary to find suitable sites of adequate size for near surface and geological repositories to accommodate the radioactive waste to be disposed and redisposed of in accordance with international standards.

All things considered, the general conclusion would be that radioactive waste management is a key issue in the conversion of the Chernobyl sarcophagus into an ecologically safe system and the task itself is one of the greatest challenges in modern society. Ukraine alone is not up to this challenge and the only way to cope with the task is to internationally share the burden by providing this country with an adequate technical and financial assistance.

ACKNOWLEDGEMENTS

The comments on this paper by Mr. S.T. Belyaev (Russian Research Center "Kurchatov Institute") and Messrs. D.E. Clark, M. Laraia (IAEA Waste Technology Section), G.S. Linsley and E. Warnecke (IAEA Waste Safety Section) are acknowledged.

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CONSEQUENCES IN GUATEMALA OF THE CHERNOBYL ACCIDENT

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Because of the long distance between Guatemala and Chernobyl, the country did not undergo direct consequences of radioactive contamination in the short term. However, the accident repercussions were evident in the medium and long-term, mainly in two sectors, the economic-political and the environmental sectors.

1) Economic-political consequences:

Guatemala is a developing country suffering an economical crisis since the early 80's, which has increased the pouverty levels. As consequence, several developed countries, mainly of the european comunity, have assisted to Guatemala donating foods like powder milk, canned meat and fish, cereals and others. The foods have been distributed in the most needed populations.

In 1986, when the Chernobyl accident happened, Guatemala had not any laboratory with capability for determining if the imported or donated foods were radioactively contaminated. Thus, several samples of food coming from Europe were sent to Chile and other countries, to be analyzed. Some samples turned out contaminated by cesium-137 and strontium-90 in low levels, mainly the powder milk and milky derivatives. The government confronted the dilemma of accept or reject the contaminated foods, in momments when the external aid would be of capital importance for the most needy people. Since Guatemala had not regulations concerning with permissible maximum concentrations of radionuclides in foods, the recommended by the european community were adopted.

On the other hand, after the accident, several countries decided to demand the certification of the levels of radioactive contaminants in products imported from Guatemala. That decision created the need for certificating such levels in exportation products like banana, coffe, sugar, cardamom and marine products. The products mentioned represent the larger part of the country currency incomes.

To face up the two problems mentioned above, the government determined the establishment of a laboratory with analytical capability to quantify radioactive contamination levels in food and environment and, to assess the government in the taking of decisions regarding similar events that may occur in the future and that could have direct consequences over the country. In this way, the Nuclear Analytical Laboratory was created within the framework of a Technical Cooperation Project with the IAEA in 1988, wich included also, the training of personnel to carry out the tasks of analytical chemistry and detection methods.

Thus, have been performed studies on imported products like powder milk, the which has showed cesium-137 in levels non nocives for the consumer (1).

Also, it has been determined that the cardamom absorbs cesium-137. The cardamom seed generates currency incomes plus than US $ 60 million yearly as exportation product (2), and shows cesium-137 levels among 2 and 8 Bq/Kg as mean. The seed is exported mainly to the arabian countries, due to its aromatic oil.

2) Environmental Consequences:

In 1990 began the government project "Radioactive and Environmental Contamination", in which framework were determined the levels of environmental radioactivity background in soils and grass of 20 provinces of Guatemala, mainly in agricultural regions. Concentrations of cesium-137 were determined among 1 and 8 Bq/Kg, in soil (3). The fraction corresponding to the Chernobyl accident was not determined because of the lack of data before the event. The levels of total and residual beta activities were also determined in the same samples, which work included the modification of a conventional method for calculating the curve of sample autoabsorption (4). The highest contamination concentrations were located in the northern zone of the country, where also the rain precipitation is higher than the other zones and where the cardamom is cultivated.

It was performed a study about the utility of the native mushrooms of the central region of the country, as bioindicators of contamination by cesium-137. Levels among 2.2 and 9.0 Bq/Kg were found in the mushrooms and levels from 1.9 to 2.7 Bq/Kg in the soils where the mushrooms grow (5).

The most important conclussions derivated from the studies before mentioned, are that the guatemalan environment has been affected by nuclear tests performed during the present century and by the Chernobyl accident. The distribution of the radioactive contamination is nearly to be uniform in the whole country, showing little variations, especially the northern regions where are found the higher levels. The found levels are useful as reference levels for future studies and for controling the environmental radioactivity background, which make easy the determination of the impact of environment contaminant events that could take place in the future.

The information is useful for the central american region, because of its geographic uniformity and its territorial extension that makes the climatic characteristics be similar. The importance is high, since the other central american countries have not local information about levels of environmental radioactive contamination.

The second study about environmental radioactivity in the whole country was started in 1994, and it shows the changes in the concentration of the radionuclides of importance and the modifications in the quantitative methodology. Also, this study includes the determination of alpha and beta-emitter radionuclides of environmental importance.

This year started the project "Radioactivity and contamination of the marine environment", which is a technical cooperation project with the IAEA. This project contemplates the determination of radionuclides and metals concentrations in sediments, water, bioindicators and marine products in the seas of Guatemala. The results are of high importance since Guatemala has coasts in the Atlantic and Pacific oceans, while the central american regions presents lack of information about marine radioactivity. The information will allow the comparation between the two environments and will contribute to define the strategies in marine environment matter.

In consequence, the Chernobyl accident has signified for Guatemala, the starting point for a) the preparation for facing up possible future events that may contaminate the guatemalan foods and the environment. b) taking decisions regarding international trade and the population health, especially when in the future is foreseen the proliferation of nuclear power plants, like the two existing since 1991 in Mexico, country next to Guatemala.

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RISKS AND BENEFITS OF THE INTERVENTIONS AIMED AT MINIMIZING NUCLEAR DAMAGE IN THE CHERNOBYL ACCIDENT

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1. Introduction

The damages that the absorption of ionizing radiation (i.r.) can cause to humans may be classified as 1) nonstochastic (somatic or deterministic) or 2) stochastic (probabilistic), which result, for example, from high doses of i.r. absorbed after a serious nuclear accident. Though the Chernobyl case involved both kinds of damage, in this paper we shall deal only with stochastic damage risk, and confine our considerations to individuals who were directly affected and received high i.r. doses.

Our purpose is to provide elements on which to base future decisions on the evacuation and return of populations affected by serious nuclear accidents. Unlike the abundant literature on the subject, and as a necessary complement thereto, we have tried, within the bounds of a strict synthesis, to identify the most significant parameters appliable to single individuals rather than to the population at large, and referring solely to risks of stochastic damage.

We shall then compare these risks, to the extent possible, to those which may arise on evacuation and return.

2. Summary of the major known risks of stochastic damage [1], [2], [3], [4], [5].

The numerous studies on this subject are based on statistical information, as there is no presently known cause-and-effect relationship explaining the scientific aspects. This information is mainly based on the effects, to the extent applicable, of irradiation at Hiroshima and Nagasaki.

From these studies, it appears that the major stochastic risks can be grouped as follows:

a) risks of damage to people exposed directly to large i.r. doses;
b) risks of hereditary damage;
c) risks of intrauterine damage to fetuses through large prenatal doses of i.r.

a) Risks of damage to people exposed directly to high i.r. doses.

These risks may be restricted to carcinogenesis (onset of cancer in various organs or tissues) and roughly grouped as: 1) leukemia and 2) other kinds of cancer. As is commonly known, latency time (i.e. the interval between irradiation and appearance of stochastic damage) is very long. The age at which irradiation occurs is therefore very important both for estimating the period when lethal damage may be expected to appear, and for evaluating and identifying other causes which may provoke damage of the same kind.

The problem of the relationship between the age at which irradiation occurs and the age of consequent death is still debated, and is based on statistical data collected and analyzed over half a century.

Based on these statistics and on the relationship between age at irradiation and age at death, we suggest classifying individuals in four categories according to their age at the time of irradiation:

1) children: irradiated before 10 years of age
2) adults I: irradiated between 11 and 29 years of age
3) adults II: irradiated between 30 and 50 years of age
4) adults III: irradiated after 50 years of age

This grouping also takes into account the age at which the known cases of death by leukemia or lethal cancer occurred. The highest mortality rate -- death from leukemia before the age of 20 -- occurs in irradiated children. Mortality decreases with age at irradiation until the age of 50, then increases for people irradiated at over 50 years of age.

The second category is characterized by a high mortality rate in individuals irradiated between 11 and 29 years of age; deaths occured mainly between the ages of 40 and 49.

As noted above, these categories are only a working hypothesis, and make no claim to scientific rigor.

Based on the foregoing, we believe that in the event of a serious nuclear accident, priority in evacuating individuals who have received high radiation doses should be given to the "children" and "adults I" categories.

Accordingly, the main parameter for establishing evacuation priority is the age at which irradiation occurred. Sex is important only as regards intrauterine irradiation damage, a matter addressed below.

b) Risks of hereditary damage

Individuals who receive high doses of i.r. during their reproductive age -- about 30 years long -- may transmit damage to future generations. These "hereditary effects" vary in nature and intensity; in extreme cases they cause serious illness and impairment of some bodily organs. Such effects may occur even when only one parent has absorbed high i.r. doses. Therefore, procedures for the evacuation and return of people exposed to intense i.r. should establish and take account of their age relative to reproduction.

c) Stochastic risk of fetal damage

A fetus that absorbs high i.r. doses is at risk for damages whose characteristics may vary according to the amount of time between irradiation and conception. Damage may not appear at all if only a few cells were irradiated, but if irradiation occured during the main organogenetic phase, the damage to the unborn child may be severe: organ impairment, disease (cancer) or death. Irradiation during some phases of conception has resulted in mental deficiency.

Pregnant women should therefore be evacuated immediately after the accident, then evaluated for risk according to the length of time since conception. The same considerations apply to their return. As noted repeatedly above, these risk assessments are based on known statistics, hence they are approximate and cannot be taken to have scientific precision.

3. Monitoring and return of evacuated individuals

Based on the above considerations, remaining uncertainties and existing hypotheses, the following factors regarding individuals in the population affected by a serious nuclear accident should be taken into special account:

a) As regards carcinogenesis risk:
- age at the time of irradiation (the classification given above can be used to the extent possible).

b) As regards the risk of hereditary effects:
- individuals of reproductive age present at the time of irradiation, irrespective of sex, since risk to offspring is due to high i.r. doses absorbed by either female or male-gonads.

c) As regards the risk of intrauterine effects:
- women in the various stages of pregnancy.

These parameters should be known and regularly updated in order to allow appropriate measures to be taken in the event of a severe nuclear accident.

In short, we propose to add to the general considerations normally cited in regard to events involving the absorption of large i.r. doses the particular considerations stated above in points (a), (b) and (c), which apply on a person-by-person basis to the population present at the time of an accident. However, these particular considerations refer to large i.r. doses received under accident conditions, hence their entity cannot be foreseen. Individualized decisions on evacuation can be taken in the manner described above, but will depend in any case on i.r. absorption assessments made at the time.

In the case of Chernobyl, it was decided (based on expert opinion) to take 350 mSv as the evacuation dose,* and the population was removed from areas where this value was thought to obtain to others where doses, though high, were obviously lower. The Chernobyl evacuation was carried out in successive stages and the relevant decisions were always based on estimated high doses.

In some countries, the value of 50 mSv, or even 100 mSv, has been taken as the threshold for temporary evacuation.

* [4] ICRP 63 (4.4.2) recommends a whole-body dose of 0.5 Sv, multiplicable by a factor of 10, but no higher, as the evacuation criterion in extraordinary and severe situations.

Accordingly, it is obviously necessary not only to establish the dose that requires evacuation at the time of an accident, but also individual doses in the areas to which the evacuated population has been removed.

After evacuation, action must be taken to:

a) reduce doses wherever possible, targeting water and food supplies in particular;
b) institute long-term monitoring of individuals at risk for:
   - carcinogenesis: check organs susceptible to leukemia or tumor, especially for categories 1 and 2, based on known statistics;
   - hereditary effects: checks regarding:
     1 - the presence and age of people in reproductive age;
     2 - the presence of children, and any signs of these effects in them;
   - intrauterine damage: check for possible effects on fetuses according to length of time since conception.

4. Return

Evacuation leads to a state of distress, due to a variety of situations that can mainly be grouped as:

a) environmental (climate, time zone, dietary habits, logistics, etc.);
b) affective (separation of family members, adjustment to new social groups, etc.);
c) health-related (due to high i.r. doses received and/or to pre-existing disorders emerging at this time, etc.);
d) psychological (due to trauma related to the accident and/or other causes varying from person to person).

Return may reduce distress conditions but lead to further absorption of i.r., thereby re-exposing individuals to the risks described above.

As noted above, however, effective controls and restrictions can reduce the risk of stochastic damage for some categories, especially in relation to the maximum-dose values established for evacuation and return.

More particularly, people at cancer risk can be allowed to return home (provided, obviously, that doses in the home area are lower than for evacuation) if individually monitored for the onset of tumors due to i.r. absorption. The importance of such checks naturally decreases from category 4 to category 1. The reduction of risk for hereditary effects refers to people in reproductive age, hence appropriate checks can be targeted at and limited to that age group. Children conceived by irradiated parents (whether or not at the time of irradiation) should be monitored very closely. Maximum caution must be used in judging the feasibility of return for people in reproductive age. Lastly, irradiated unborn children should be monitored up to the time of birth; in light of present uncertainties, the evacuation of pregnant women should be maintained until after childbirth.

The types of monitoring listed above do not require the individuals concerned to remain in the relocation area unless their return would lead to further absorption of fairly high doses. Dose values in return areas should be established by the competent authorities, taking account not only of the incremental i.r. risk, but also of risks related not to i.r. doses but to the distress caused by being away from home.

This requires instituting case-by-case evaluation of the risk of damage due to absence from home compared with the risk of damage due to further i.r. absorption upon return to the home area. To state the obvious, the comparative risk assessment will depend on estimated i.r. doses in the return area.

At this point, the responsibility for the decision on return falls to the competent authorities, who should be in a position to evaluate the pros and cons of incremental risk on the basis of the statistics mentioned above.

5. Conclusions

The phases of evacuation and return can be planned out in a way that minimizes risks and perhaps assures maximum benefits. However, it is essential to base all actions on clear knowledge of the data listed and briefly described in this paper. These data must naturally be appropriately aggregated and completed with other data gathered and made available in other scientific studies and publications.

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IMPACT OF THE CHERNOBYL FALLOUT IN THE ALPINE ENVIRONMENT

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INTRODUCTION

In Austria the alpine regions received the highest fallout contamination, showing a very inhomogeneous spatial distribution of the surface deposition. About half of the national territory is within alpine regions, which are very different in terms of underlying bedrock and soil characteristic. Since this is the controlling factor for the radionuclide uptake of the vegetation, it is crucial for the long-term effects of radioactive fallout. Different studies have been carried out in the Province of Salzburg (area: 7154 km^2) over the past ten years, addressing a broad spectrum of issues, such as: measurement of the spatial distribution of the fallout, research in monitoring techniques, comparison of theoretical calculations with actual in vivo-measurements of nuclide uptake by man for different population groups, and the investigation of biological effects [1,2,3,4,5].

When considering the radioecological effects of the Chernobyl fallout a distinction has to be made between the short-term effects immediately following the fallout and the long-term effects. While the short term effects are controlled by the physical characteristics of the fallout, similar for the whole region, the long-term effects are more determined by the radioecological properties of the environments affected which are much more variable than the fallout-characteristics.

SITUATION IMMEDIATELY FOLLOWING THE CONTAMINATION

The hot particle issue

The controversy about hot particles was initiated by Tamplin and Cochran [6] who contended that inhalation of hot particles containing a certain amount of alpha emitters represent a substantially higher lung cancer risk than if the same amount of radionuclides were distributed among smaller sources. While Mayneord and Clarke [7,8] also estimated a higher risk for ^{239}Pu hot particles at sufficiently small activities, they predicted a reduced risk for high activities relative to a uniform nuclide distribution. More importantly, however, they also observed the same tendency for beta emitting hot particles (^{86}Rb, ^{35}S). In the wake of the Chernobyl incident, Hohenemser et al. [9] raised again the question whether a ^{103}Ru hot particle is indeed more carcinogenic than uniformly distributed nuclides of the same total activity.

In the Chernobyl fallout hot particles of mostly β-emitting radionuclides have been detected in several countries varying considerably in radionuclide composition, activity, size and shape. These hot particles can be grouped into two categories: (i) particles originated in a process of condensation of vapours of ruthenium, consisting of pure ^{103}Ru and ^{106}Ru (category A); and (ii) fuel fragments containing, besides the ruthenium isotopes, ^{141}Ce, ^{144}Ce, ^{95}Zr, ^{95}Nb, ^{134}Cs and ^{137}Cs (category B). For the assessment of the radiological risk associated with the inhalation of hot particles in the Austrian Alps, data reported from Austria [10,11], Germany [11,12], Hungary [13] and Switzerland [14] had to be used since no systematic measurements of hot particles have been carried out in this region. Based on these measurements, the following assumptions were made concerning activity, concentration in ambient air, and size: (i) hot particles are composed entirely of ^{103}Ru with activities of 30, 300, and 3000 Bq, reflecting the distribution of hot particles measured in Central Europe [5,7,8,9]; (ii) the average hot particle concentration is $1x10^{-3}$ m^{-3}, reflecting observed concentrations in the range of $5x10^{-5}$ to $5x10^{-2}$ [8,9]; and, (iii) the average geometric diameter of the hot particles is 1 μm [6,9].

For the risk assessment of hot particles via the inhalation pathway, an average respiratory minute volume of 15 l min^{-1} and mean exposure time of one week was assumed. Based on a deposition probability of about 20% for 1 μm particles in the pulmonary region (note: particles deposited in the bronchial region are cleared to the GI-tract within a couple of hours), the probability to inhale and deposit a hot particle in the deep lung is about 0.03. Since the probability to find more than one hot particle in the lung is very small (for two hot particles it is $4x10^{-4}$), higher concentrations of hot particles in the inhaled air will increase the number of individuals inhaling a hot particle rather than the number of particles deposited per person.

For insoluble ^{103}Ru particles with clearance half-times of the order of hundreds of days, we assume that a hot particle, once deposited, will be retained in the lung for 1 year. This leads to a cumulative activity of about 17 kBq.day for a 300 Bq ^{103}Ru hot particle integrated over one year.

Lung cancer risk calculations are based upon the initiation-promotion model of carcinogenesis. In this model, initiation is interpreted as cellular transformation in surviving cells, while promotion is related to cell killing in the immediate vicinity of the transformed cells [15]. For a uniform nuclide distribution, lung cancer risk is expressed as a function of the average dose received by each cell. In the case of a hot particle, however, with a radial dose distribution around the hot particle, a few cells close to the hot particle will receive relatively high doses, while the majority of cells will not be hit at all. For these dose calculations, a lung mass of 1 kg with a density of 0.26 g cm^{-3} was assumed.

Calculations of the lung cancer risk as a function of the radial distance from the hot particle indicate that all cells in the immediate neighbourhood will be killed due to the very high doses, so that no tumour can arise. At intermediate distances from the hot particle (between 0.7 and 0.8 mm), the probability for cellular transformation and promotion exhibits a distinct maximum, dropping off sharply at greater distances.

The probabilities for lung cancer induction, obtained by integrating over all radial distances, are given in Table 1 for three selected hot particle activities and compared with the corresponding uniform dose distributions. First, risk is computed for a stationary hot particle, i.e., a particle remains at a given site for one year (denoted e.g. as 1 x 300 Bq). In this case, the 30 Bq hot particle has the highest risk of the three hot particles relative to their corresponding uniform distributions, with a risk enhancement factor of 33. Particles *in vivo*, however, do not remain localized for such long periods of time, but instead are continuously moving throughout the pulmonary region. For example, movement of a single 300 Bq particle may be simulated by the action of 10 smaller 30 Bq particles (denoted as 10 x 30 Bq), which is equivalent to one 300 Bq particle staying at 10 different non-overlapping sites for each 1/10th of a year. In general, particle movement increases lung cancer risk for a given activity, producing the highest risk for the most mobile hot particle. Corresponding calculations for other organs with unit density tissue display a similar pattern of response, though risk enhancement factors relative to the

Table 1: Lung cancer probabilities for stationary and moving ^{103}Ru hot particles in the lungs. (L) (density = 0.26 g cm^{-3}) and in other organs (O) with unit density compared with the corresponding uniform radionuclide distributions.

Carcinogenic risk* (arbitrary units)	^{103}Ru beta activity (Bq)					
		3000			300	30
	100 x 30	10 x 300	1 x 3000	10 x 30	1 x 300	1 x 30
Uniform (L,O)	2.3x10^3	2.3x10^3	2.3x10^3	2.3x10^2	2.3x10^2	2.3x10^1
Hot particle (L)	7.5x10^4	2.5x10^4	5.6x10^3	7.5x10^3	2.5x10^3	7.5x10^2
Hot particle (O)	5.2x10^3	1.4x10^3	2.0x10^2	5.2x10^2	1.4x10^2	5.2x10^1

*Additional gamma component risk: 8.8 (30 Bq), 8.8x10^1 (300 Bq), and 8.8x10^2 (3000 Bq) uniform distributions are reduced by approximately one order of magnitude. Thus, if a hot particle is cleared from the lungs and then trapped in an organ with unit density for a longer period of time (note: the same applies to ingested hot particles), the hot particle effect is smaller there than in the lungs. Simultaneously emitted gamma radiation produces a rather uniform distribution of risk even in the case of a hot particle, which has to be added to the risk of the beta components listed in Table 1.

In conclusions, risk enhancement factors for a ^{103}Ru hot particle, computed relative to a uniform radionuclide distribution of equal activity, are highest for small and intermediate activities and for hot particles moving in the lung. Similar results will be obtained for other beta-emitting radionuclides of comparable half-life and energy, such as ^{95}Zr, ^{95}Nb, ^{140}Ba, and ^{141}Ce. While inhalation of these hot particles might exceed all other exposure pathways of the Chernobyl fallout, its potential lung cancer risk is still smaller than that for radon progeny inhalation and is thus unlikely to be detected against the reported natural lung cancer incidence.

Chromosome aberration / Effect on blood chromosomes

An increase of chromosome aberrations in peripheral blood lymphocytes of persons living and/or working in an environment with elevated radioactivity has been found in various places of the world and the data indicate that the increase occurs already at rather low doses [4]. Therefore we chose 16 volunteers from Salzburg city for blood sampling during 1987 whose additional external and internal doses at that time were between 15% and 68% of the total pre-Chernobyl environmental burden (0.9 mGy/yr). On the day of blood sampling for cytogenetic investigation (June, 9 and July, 27) the ^{137}Cs content was measured with a whole body counter. From these results the adequate ^{134}Cs content and from the dose commitment to the tissue (UNSCEAR 1982 model: $P_{4,5} = 2{,}4 \times 10^{-6}$ Gy/Bq x kg^{-1}) the entire internal Cs dose was calculated. The average external gamma dose for Salzburg, based on several measurements at many different sites and times, was found to be 0.12±0.02 mGy/yr in 1987.

The Cs dose for the volunteers investigated ranged from 0.013 to 0.492 mGy/yr. They were at ages from 24-69 years, all non smokers, took no drugs and had no diagnostics x-rays within the last year. The procedure of lymphocyte culture, slide preparation and scoring followed a standard method at that time with 48hrs culture time. The different coded slides were distributed for scoring to laboratories, chosen according to their former scoring variabilities being only within statistical errors. Altogether 23060 metaphases were analysed.

Two of the volunteers (a female, age 38, and a male, age 24 years in 1985) were also taken as controls for other investigations so we had chromosome aberration data from the years 1984/85 and also 1988 and 1990. Their mean external plus internal additional dose rates in April 1988 and in January 1990 were 0,16 and 0.09mGy/yr respectively.

Because of the low-doses and the resulting low effects we summarised for statistical reasons all chromosomal aberrations („totals" = dicentrics [D]+ centric and acentric rings [R]+ interstitial and terminal deletions [ID, TD]) and pooled the results for several persons. The mean values are weighted according to the number of metaphases scored. The totals from all volunteers investigated 1987, including those for the two persons in 1984/85, 1988 and 1990, are given in Table 2 and plotted in Fig 1 [5]. From the table it is obvious that in 1987 an unusual high amount of rings occurred. All of these rings were confirmed by two different scorers in each laboratory. The dicentrics recorded in 1987 were between a factor of 3 and 4 higher than the pre-Chernobyl values. Moreover 1987 we found a diploid cell with 6 ID in 736 metaphases (not included in Table 2a). In the same year in an in-vitro investigation, applying additional low α-dose from ^{214}Po, three cells with large numbers of ID and TD were found: one cell out 57 metaphases (additional α-dose: 0.38 mGy), one out of 141 metaphases (additional α-dose: 1.65 mGy) and one out of 517 metaphases (additional α-dose 420 mGy). Because these damages usually are expected at higher doses and the additional α-dose was low, it might be assumed, that they were caused by the increased background radiation following the Chernobyl fallout.

Table 2: Mean aberration frequencies per 100 metaphases in blood-chromosomes of Salzburg residents

a) 16 different blood donors, sampled 1987

Mean additional dose ^{134}Cs+^{137}Cs [mGy/yr] internal	external	Nr. of persons (year)	Metaphases scored	Total numbers D	R	ID+TD	Percentage of aberrations D	D+R+ID+TD
0.07	0.12	3 (1987)	4861	13	10	27	0.27±0.07	1.02±0.15
0.14	0.12	4 (1987)	3327	8	9	41	0.24±0.09	1.74±0.23
0.26	0.12	4 (1987)	3847	10	7	40	0.26±0.08	1.48±0.20
0.39	0.12	5 (1987)	3575	7	2	40	0.20±0.07	1.37±0.20
b) 2 different blood donors, sampled prior and after the accident								
< 0.01	< 0.01	2 (1985)	4270	3	0	8	0.07±0.04	0.26±0.08
0.18	0.12	2 (1987)	2907	11	12	32	0.39±0.11	1.89±0.26
0.08	0.08	2 (1988)	756	4	0	3	0.53±0.26	0.93±0.35
0.02	0.07	2 (1990)	2424	1	0	14	0.04±0.04	0.62±0.16

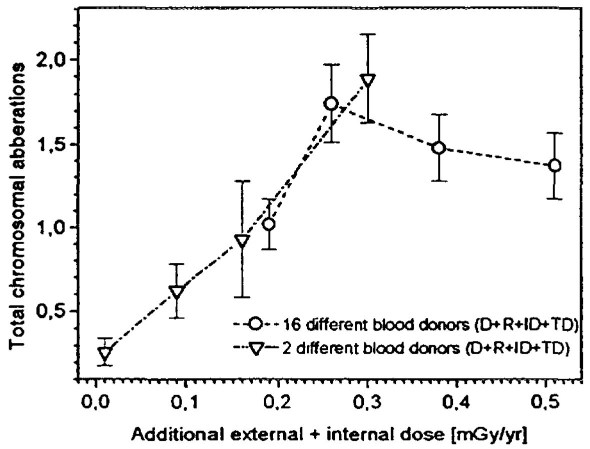

Fig.1. **Chromosomal aberration in blood chromosomes of 16 different donors as a function of additional internal and external dose received after the Chernobyl fallout.**

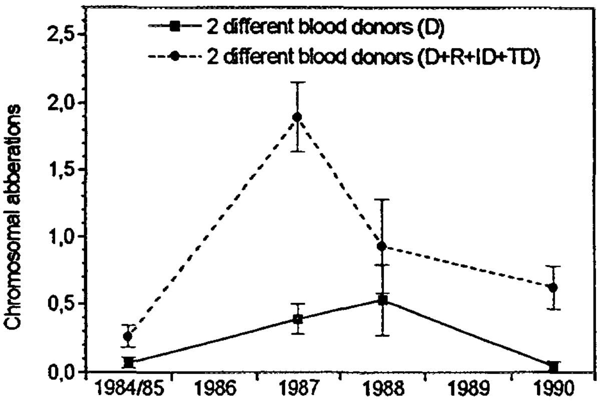

Fig.2. **Chromosomal aberration in blood lymphocytes of 2 different donors as a function of time.**

PRESENT SITUATION

Analysis of a large number of soil-depth profiles and lichens as biological monitors, sampled from 1986 to 1995, revealed a rather inhomogeneous nuclide deposition pattern in the Province of Salzburg, varying between 10 GBq/km^2 and 80 GBq/km^2 [3] for ^{137}Cs. This inhomogeneity is largely due to different meteorological conditions prevailing at the time of passage of the radioactive cloud.

At present the only remaining radionuclides of significance from the Chernobyl fallout are ^{137}Cs and, with minor importance, ^{134}Cs. These nuclides enter the food chain to a varying degree and contribute to the ambient gamma-exposure affecting the dose of the population by these two ways. Due to the half-life of 30 years for ^{137}Cs its contribution to the gamma-exposure is still of significance and it has been demonstrated (Fig.3) that though the migration into deeper soil layers proceeds and increasingly attenuates the gamma-flux, the average increase of gamma-exposure was calculated to be 14.2 nSv/h/10 kBq/m^2 in 1993 [3]. This causes an additional gamma-exposure ranging between 30% and 100%, of the pre-Chernobyl background. Especially upland regions are affected by this contribution in a twofold manner: (1) The increase of ambient gamma exposure is higher because the surface deposition tends to be above average, and (2) the contribution to ambient gamma-exposure decreases slower because the downward migration rates are smaller than in any other environment (Fig 3). In regions with fast migration into the soil the migration rate controls the decrease of gamma exposure and in regions with small migration rates, the exponential decay of ^{137}Cs is the more important controlling factor. The effect on the dose to the population therefore is higher in alpine regions than in other regions.

At present the average contamination of the food products with radionuclides from the Chernobyl fallout is very low and of minor radiological significance. This is due to the fact that the majority of the production areas are situated within intensively used agricultural regions where the soil-plant transfer-factor tends to be low. However, there are some regions that show a significantly different behaviour in terms of nuclide transfer. These regions are exclusively situated in elevated alpine areas. They are used for agricultural production only to a low degree, i.e. their contribution to national food production is minor. The term "upland ecosystem" might be most suitable for these seminatural environments, mainly alpine pastures with poor vegetation in agricultural terms and the food production being exclusively dependent upon grazing animals. The main radioecological feature of these alpine pastures is their high transfer-factor, which can be correlated with the bedrock geology controlling the formation of the soil: While in limestone regions the transfer-factors are small and similar to the main agricultural production sites, these factors from the alpine pastures with silicic bedrock geology can be extremely high [2]. In areas with high transfer-factors according to specific soil conditions, the locally produced food can still show significant levels of food contamination. Such areas are distributed over the Hohe Tauern region with the highest elevation in the Austrian Alps, where agricultural production during the summer time is common. The contamination of food products from these areas, which are exclusively based on grazing cattle, can still reach up to 30%-40% of the levels measured in the initial period immediately following the fallout deposition. Some production-sites were selected for continuous sampling of milk during summer. The evaluation of these data shows that the average contamination of milk from these sites decreases with an effective half-life between 3 years and 6 years (Fig.4), depending on the production site. These half-life times differ significantly from the major milk-production areas, where the effective

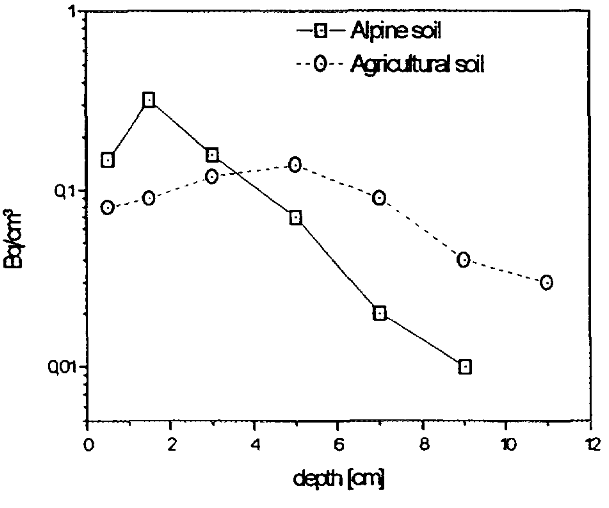

Fig 3: Soil profile of ^{137}Cs in two different soil types: (○) Intensively used agricultural soil, (□) Alpine soil from upland ecosystem, extensively used. Data normalised to 1 Bq/cm^2.

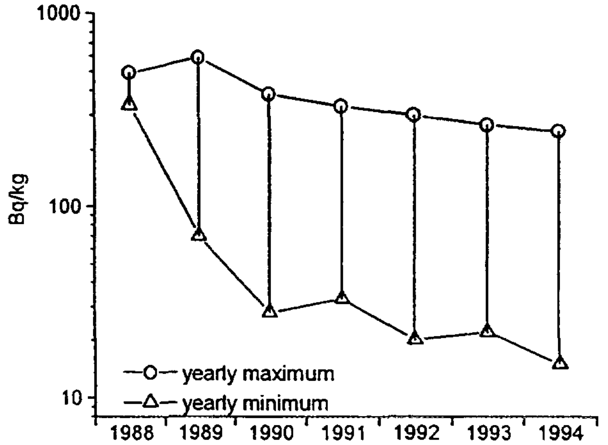

Fig 4: Time-dependent ^{137}Cs-activity concentration in milk from regions with high transfer factors.

half-lives are between 500 - 800 days [16]. Other agricultural products made from milk and the contamination of cattle are affected in a similar way. The peaking of the contamination is restricted to the summer period because the amount of winter forage produced in the regions, where high transfer factors dominate, is negligible. People mostly affected by the consumption of food with high radionuclide content are a small group of seasonal workers on the production sites. Whole body measurements of this population group from 1991 and 1992 showed that the ^{137}Cs activity concentration is comparable to the average values for Austria in 1987, when the average whole body burden reached its maximum [17]. The measurements were made before the working season and shortly afterwards. In both years, 1991 and 1992, the ^{137}Cs content raised significantly during Summer: on average the values measured after the summer season had doubled, with only low significant differences between 1991 and 1992. For the calculation of the daily intake two constant daily intake rates for ^{137}Cs, one before and another constant daily intake rate during the summer working period, were assumed. Under these assumptions the daily intake was about 40 Bq/day in the summer period and 10 Bq/day during the rest of the year. Using 100 days for the summer period and applying a biological half-life for ^{137}Cs of 100 days and a recommended dose conversion factor for Cs [18] the average radionuclide uptake corresponds to an additional ingestion dose of 75 μSv in 1991 and 1992.

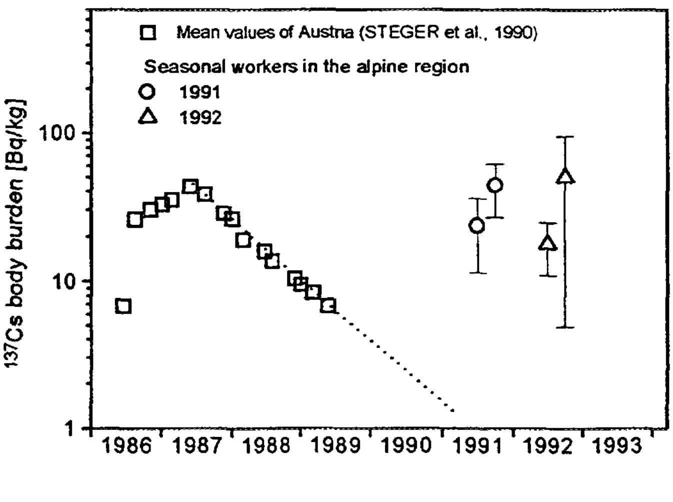

Fig.5: Average ^{137}Cs body burden in Austrian residents vs. time compared to seasonal workers of alpine areas

In this investigation blood chromosomes of nine workers were recorded prior to and after their summer-stay in the alpine regions. The entire individual radiation burden, consisting of external gamma dose, internal alpha dose (from radon and daughters) and beta dose (from ^{137}Cs, ^{134}Cs and ^{40}K) was calculated from outdoor, indoor and whole body measurements. The results obtained from this study [19] are indicative of a similar dose-effect relationship as found for the study group of urban dwellers in Salzburg City from 1987, when a significant increase of chromosome aberration after the Chernobyl fallout could be found. In view of the low dose values observed, no biological effects are to be expected, with the exception of chromosomal aberrations.

CONCLUSIONS

In the period immediately following the Chernobyl fallout deposition in the Alpine region, hot particles as a dominant factor for the dose to the public considered. Due to their high risk enhancement factors relative to a uniform distribution, inhalation of hot particles might exceed the significance of all other exposure pathways of the Chernobyl fallout.

Chromosome aberrations, following low dose irradiation of the Chernobyl fallout, could be observed.

Considering long-term consequences, regions with high transfer factors are affected by a prolonged period of increased uptake of radionuclide into the food chain. In the alpine region of Austria these regions can be found at elevated sea-levels within seminatural upland ecosystems of poor agricultural use. The effective half-life of the average contamination with ^{137}Cs in food products from these regions varies between 3 and 6 years.

The population group mainly affected are the workers on the seasonal production sites Whole-body counting data from 1991 and 1992 are in the same range as the highest average values in Austria shortly after the Chernobyl fallout Average individual dose values are 75 μSV in 1992 and can be considered relatively low

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MEASUREMENTS OF THE PRESENT RADIATION LEVELS IN RESIDENTIAL AREAS AROUND CHERNOBYL

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1. INTRODUCTION

JAERI and RIAP concluded the "Agreement on the Implementation of Research at the Chernobyl Center for International Research" on 1992 aiming to analyze environmental radiological consequences in the Chernobyl areas. On the basis of this agreement JAERI has performed environmental research in some different phases in cooperation with RIAP. In this paper, results of measurements on external gamma-ray dose rates in residential areas around Chernobyl will be presented. Measurements have been made using portable dose rate meters to clarify the present radiation levels inside and outside houses in which people still live. Further, wider regions have been covered with carborne surveys. The radiation levels and characteristics found in these measurements will be discussed.

2. MEASUREMENTS OF GAMMA DOSE RATES INSIDE AND OUTSIDE HOUSES IN SETTLEMENTS IN THE 30 km ZONE

2.1 Method

At 7 settlements in the 30 km zone, the absorbed dose rates in air inside and outside 47 houses were measured. The locations of the settlements are illustrated in Fig.1. Though Kupovatoe and Teremci are farther than 30 km from the nuclear power plant(NPP), they are substantially included in the 30 km zone for entrance restriction. The portable dose rate meters, SWING and DBM, developed at JAERI were used in the measurements. These instruments can promptly provide accurate dose rates averaged over any time interval utilizing the spectrum-dose conversion function (G(E) function) method[1]. Measurements were made at several points both indoors and outdoors for each house, and the

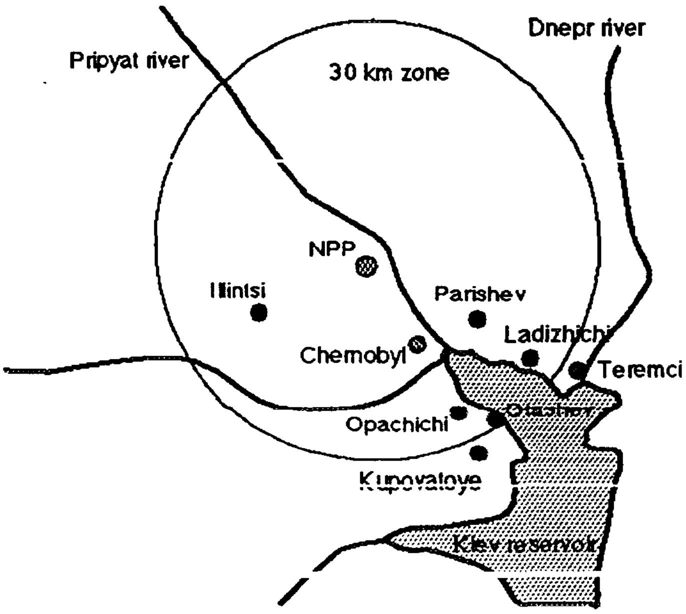

Fig. 1 Locations of the settlements where indoor and outdoor in-situ measurements were made.

averaged dose rates were taken to be the representative values for the house All of the houses were separated and made of wood or brick As the measurements have been continued since 1992, there must be change in radiation levels according to time elapsed However, no correction was made for this change, because the change would be expected not significant considering the long half-life and stability of Cs-137 which is the dominant nuclide contributing to the external doses at present

2.2 Results and discussion

Table I gives the ranges and averages of indoor and outdoor dose rates with the indoor/outdoor dose rate ratios The frequency distributions of dose rates and indoor/outdoor dose rate ratios are shown in Fig 2 The outdoor dose rates showed a range from 69 to 259 nGy/h, the mean value being 123 nGy/h The indoor dose rates changed between 34 and 135 nGy/h around the mean value of 62 nGy/h The difference in radiation levels with settlements was generally not so large, but the mean dose rate in Opachichi was almost twice as much as those in the other settlements both for outdoor and indoor The dose rates in Otashev were slightly higher than the average However, still the dose rates in the settlements are not very high they are comparable to the natural radiation levels reported in the world[2] The shapes of dose rate distributions are similar between indoor and outdoor They have peaks in relatively low dose rate regions and tails in higher dose rate regions due to the relatively higher values observed in Opachichi and Otashev Nearly 50% of outdoor dose rates are between 80 and 120 nGy/h, and more than 60% of indoor dose rates are between 40 and 60 nGy/h

Indoor/outdoor dose rate ratios including both artificial and natural radiations varied from 0 31 to 0 80, and more than 60% of the data were between 0 4 and 0 6 Therefore, the dose rate including a natural component seems to reduce to about half in a house in the areas reported in this study

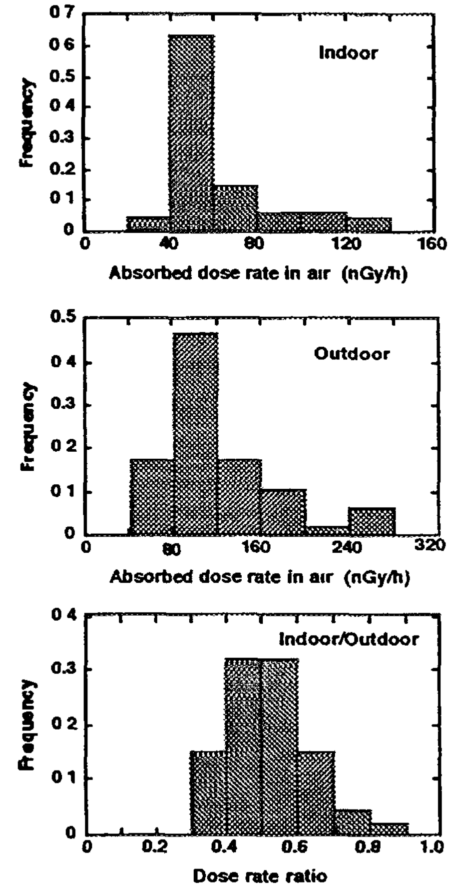

Fig 2 Distributions of indoor doses, outdoor doses and the indoor/outdoor dose rate ratios measured in settlements in the 30 km zone

To analyze the shielding effect of houses in the Chernobyl area against gamma rays from anthropogenic nuclides, detailed measurements with a NaI(Tl) spectrometer were performed in a typical wooden house After subtracting the dose rate due to natural gamma rays estimated from spectral information, the indoor/outdoor dose rate ratio for artificial gamma rays was estimated at 0 3

At the same time computer simulation for the shielding effect of the house for Cs-137 was performed A model of the house was constructed according to the results of careful measurements of the dimensions and effective wall thicknesses Monte Carlo calculations[3] performed using this model showed an indoor/outdoor dose rate ratio similar to the measured value Considering thinner wall thicknesses in the simulation made the indoor/outdoor ratio larger because of less shielding effect However, even if very thin walls were assumed, still the indoor dose was obviously smaller than the outdoor dose This is because there is no gamma ray source inside the house The detail description of this computer simulation will be presented elsewhere

Table I Ranges and averages of gamma-ray dose rates inside and outside houses in 7 settlements measured with portable dose rate meters.

Settlement	Number	Absorbed dose rate in air (nGy/h) Indoor Range	Indoor Mean	Outdoor Range	Outdoor Mean	I/O Ratio Mean
Kupovatoye	15	34- 70	50	89-141	112	0.45
Opachichi	7	77-125	105	163-259	215	0.49
Otashev	7	58-135	76	108-198	140	0.54
Illintsi	4	51- 62	56	72-106	84	0.68
Parishev	7	35- 57	48	73-113	97	0.49
Teremci	4	43- 55	49	69- 84	77	0.65
Ladizhichi	3	51- 59	54	79-136	105	0.53
Total	47	34-135	62	69-259	123	0.52

3. CARBORNE SURVEYS IN AND OUT OF THE 30 km ZONE

3.1 Method

Carborne surveys over wider areas were carried out using a mobile survey system developed at JAERI whose block diagram is indicated in Fig.3. Dose rates were measured continuously with the dose rate meter DBM. A detector fixed to a pole was extended behind a car to prevent the shielding effect of the car body. In addition, the positional data of the car were obtained from a Global Positioning System(GPS) utilizing radio communications with satellites. These data recorded every 10 seconds allowed us to construct a precise map showing radiation levels.

A four-wheel drive car was selected for the survey to stand bad road conditions. The car has been driven mostly along paved roads and sometimes on small roads in fields or forests inside and outside the 30 km zone. Since a paved road has been decontaminated, the dose rates on the road are somewhat lower than those on the fields on the both sides of the road. The ratio of a dose rate measured on board to the average dose rate in the fields has been estimated to be between 0.5 and 1.0 according to several detailed measurements of dose rate distributions around the car. The results presented in this paper were corrected for this effect considering the road conditions.

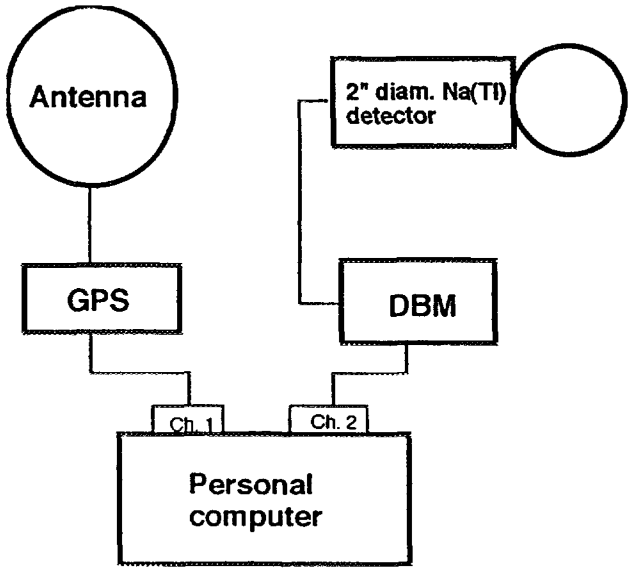

Fig. 3 Block diagram of the carborne survey system designed at JAERI.

The surveys have been performed in the southern half part of the 30 km zone, western and northern regions outside the zone and areas near Gomel and Mogilov where high contamination levels have been reported for about 20 days in total in 1994 and 1995. Because of limitations due to road conditions, entrance restriction and time available, it was impossible to cover the whole regions Nevertheless, present features of dose rate distributions in the Chernobyl area have been made clear

3.2 Results and discussion

An example of direct results of a carborne survey is shown in Fig 4 The measurement was performed moving westward from Chernobyl city to Poleskoe which is a small town located 20 km west-south-west from the 30 km zone. Then, the car turned and headed east In the figure, the track of the car reconstructed from positional data and temporal change of absorbed dose rate in air are shown. As being obvious from this figure a precise distribution of dose rates can be obtained from the measurements In this case high dose rates up to nearly 8 μGy/h were observed

In the zones, very high contamination still remains near the reactor and at the west part, while at the south and east parts the radiation levels are relatively low as found in the measurements described in Section 2 In the west and north regions just out of the 30 km zone, high dose rates up to about 8 μGy/h and 3 μGy/h were observed, respectively. In the area near Gomel and Mogilov the highest dose rate that we have ever observed is about 4 μGy/h, however we could not enter some areas because of the reasons mentioned before, and some higher dose rates would be anticipated to be observed in these areas

The dose rate distribution obtained in this study was compared with the contamination map published by IAEA in 1991[4] As the IAEA map shows contours of Cs-137 concentration per unit area, it is impossible to compare it directly with our results However, considering the facts that at present the external dose attributes mainly to Cs-137 and that Cs-137 in this region migrate very slowly into the ground, the dose rates could be estimated from the concentrations per unit area with some uncertainties The absorbed dose rates in the air were calculated using the dose rate conversion factor compiled in ICRU 53[5] on the assumption that the external dose attributes to Cs-137 distributed in the ground according to an exponential function at a relaxation depth of 2 g/cm^2

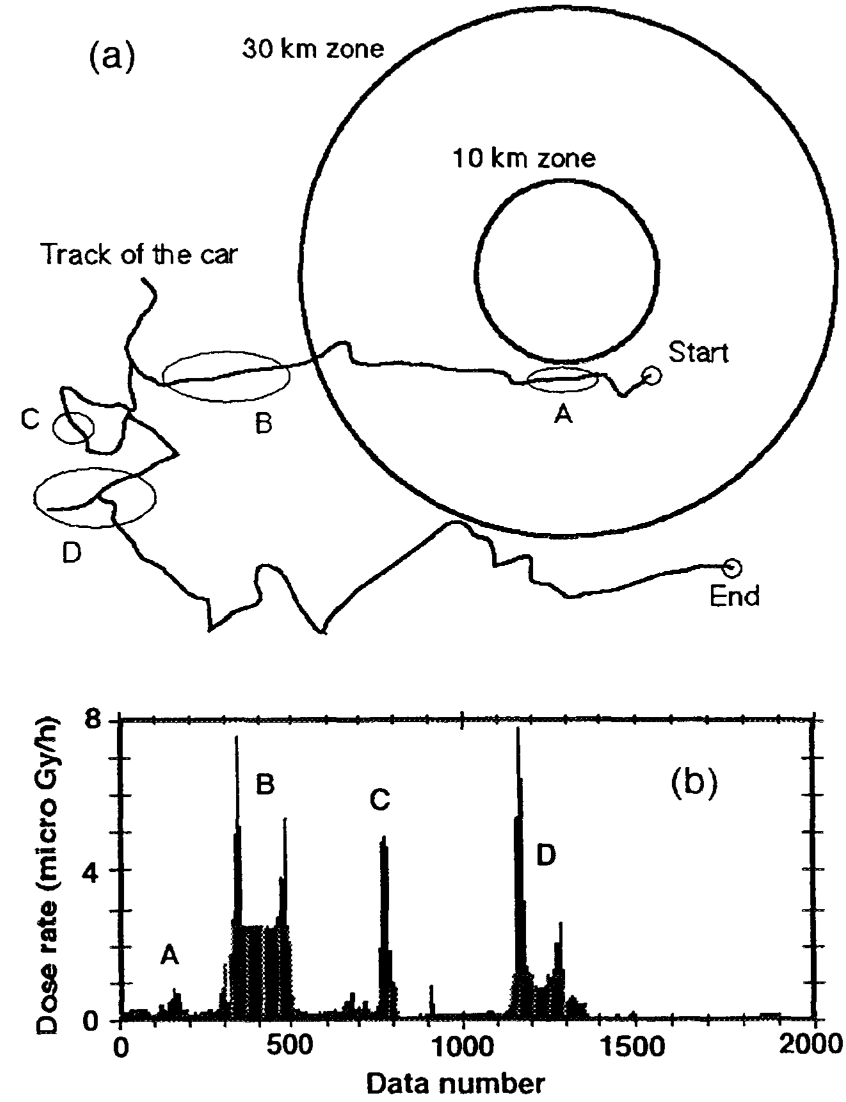

Fig 4 An example of direct results of a carborne survey (a) Reconstructed car track (b) Sequential dose rate data Dose rates averaged over 10 s were measured successively The locations where high dose rates were observed are shown in figures (a) and (b) by notations A-D

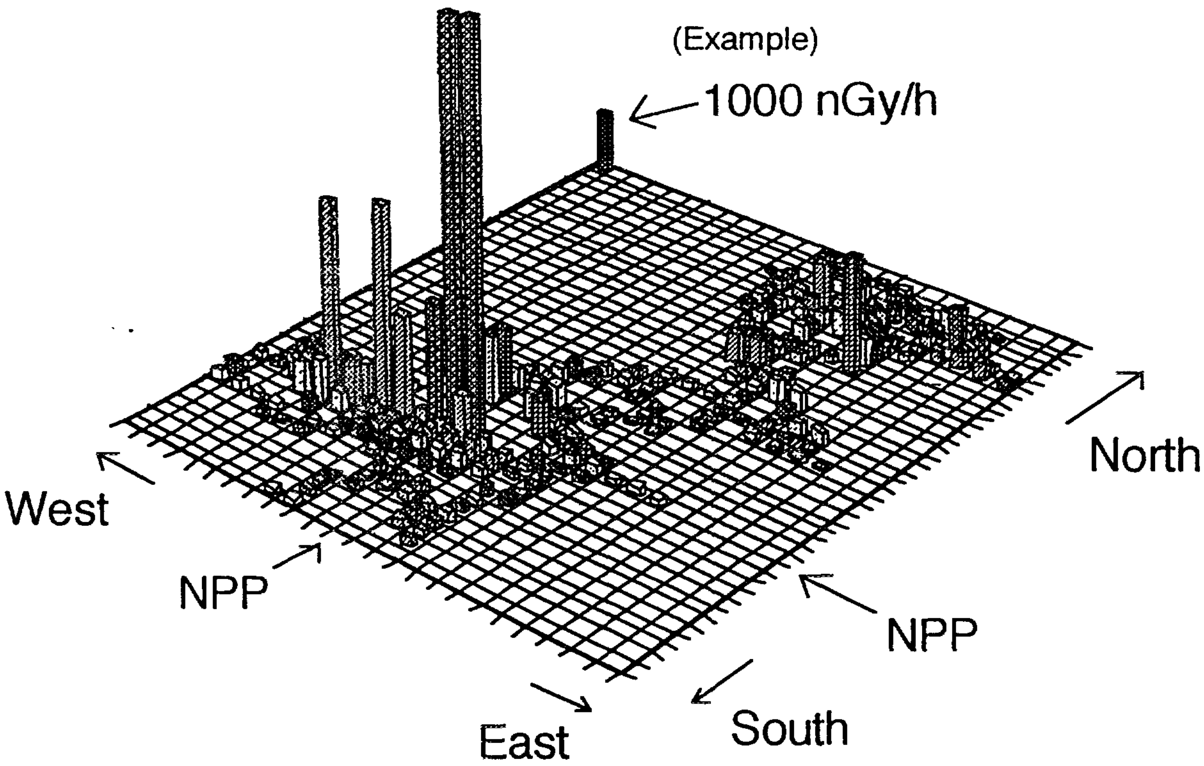

Fig. 5 Spatial distribution of absorbed dose rates in air measured by carborne surveys. The length of a bar is proportional to the average dose rate in the 10 x 10 km square region. There was no measurement made in the squares without bars.

Our results and the IAEA data showed general agreements: the IAEA contamination map was validated by in-situ measurements. On the other hand, it was found that the contamination has finer structures than shown in the IAEA map in some regions. Further, it seems that the four contour values used in the IAEA map are not sufficient to cover the wide contamination levels in this area. Here, we do not indicate the concrete data on the comparisons because they are rather complicated.

The whole survey data were integrated to produce a dose rate map in this region shown in Fig.5 where the average dose rates in 10 x 10 km squares are indicated by lengths of bars. Note that in squares without bars no survey was carried out and it does not mean the dose rates are quite low. Since a bar shows the average dose rate, the dose rate fluctuates more in a smaller range.

4. CONCLUSION

From these measurements the present features of contamination around Chernobyl have been made clear. It was confirmed that the external radiation levels in the settlements where people live are not high. Further, a precise dose rate distribution over wide area was determined from carbone surveys. The results showed a general agreement with the contamination map issued by IAEA, while some finer structures were found. These data are expected to be a help for taking countermeasures for the recovery of the Chernobyl environment and the radiation protection of people living in the areas in future. We are planning to extend the region of these measurements.

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MIGRATION BEHAVIOUR OF RELEASED RADIONUCLIDES IN THE RIVER SYSTEM IN THE EXCLUSION ZONE OF THE CHERNOBYL NUCLEAR POWER PLANT

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1. INTRODUCTION

This work has been carried out for assessment of secondary migration of the Chernobyl-derived radionuclides through a river system in terms of their amount and forms of the mobile component. It would contribute a) to clarify controlling factors which cause remobilization / immobilization of the released radionuclides for the river system in the vicinity of the Chernobyl Nuclear Power Plant, and also b) to find effective countermeasures to prevent secondary contamination in a river system after a nuclear accident. With the objectives described above, migration behavior of the radionuclides in the river system in the exclusion zone was investigated for suspended solid, bottom sediment and river water. In this paper, i) the result of radiochemical analyses for dissolved radionuclides and ii) physical form of ^{137}Cs in river waters are described and discussed.

2. EXPERIMENT

Samples for analyses of activities were collected from four sites situated at the Pripyat River (4 km east of Chernobyl City, 1 km down from a bridge of Route P-19), the Sahan River (6 km west of Pripyat Town) , the Uz River (6 km South-west of Chernobyl Town, under a bridge of Route P-10) and the Lake Glubokoye (East bank, 6 km north of Pripyat Town) in 1995 (Fig.1). The Sahan and Uz rivers are tributaries of the Pripyat river. Suspended solids and colloids were collected on filters of three pore sizes (1, 0.45 and 0.20 μm) sequentially from 100-150 liters of river water. The material of the first filter (1 μm) is cotton yawn , the second and third (0.45 and 0.20 μm) filters are made of cellulose acetate. After the filtration, "dissolved" (finer than 0.20 μm fraction) ^{137}Cs and ^{134}Cs was collected on a acrylic fiber impregnated with potassium hexacobalt(II) ferrate(II) (KCFC).

For the river water samples of Pripyat river (collected on Sept. 23 1995), Sahan River (collected on Apr. 2, 1995) and Glubokoye lake (collected on Sept. 20, 1995), dissolved ^{90}Sr and transuranic nuclides of ^{238}Pu, $^{239+240}Pu$, ^{241}Pu, ^{241}Am and ^{244}Cm were obtained by a method of co-precipitation for 20-50 liters of the filtrated water (finer than 0.20 μm fraction). Then, following radiochemical analyses were adopted. Strontium-90 was analyzed by a method of liquid scintillation counting after purification of ^{90}Sr using a cation exchange resin [1]. The transuranic nuclides except for ^{241}Pu were analyzed by a conventional radiochemical separation by ion exchange resins, followed by alpha-ray spectrometry for electro-deposited samples [2]. Plutonium-241 was analyzed by a liquid scintillation counting technique for re-dissolved electro-deposited samples. Dissolved ^{137}Cs on KCFC was measured by gamma-ray spectrometry after incineration of the acrylic fiber. Briefly, the cartridge filter of pores size 1mm for suspended form of ^{137}Cs was incinerated in an electric furnace at 450 °C for 8 hr. Then, the ash was analyzed by gamma-ray spectrometry. Details of ^{137}Cs measurement can be found elsewhere [3].

3. RESULTS

3.1 Water Chemistry

The concentrations of major ions in each sampling location were determined by the method of ion chromatography and ICP-AAS. The major constituents of the river Pripyat in the exclusion zone were Ca^{2+} (2.8-3.0 meq/l) and HCO_3^- (2.4-2.6 meq/l). The secondary constituents were Na^+(about 0.4 meq/l), Mg^{2+}(about 0.3 meq/l) , Cl^- (0.40-0.45 meq/l) and SO_4^{2-} (0.8-1.0 meq/l). The river water of Pripyat river was slightly alkaline (pH 8.5-8.7) while the river water in the tributaries (Uz and Sahan rivers) was less alkaline (pH 7.5). An important finding was high concentration of dissolved organic carbon in every water body. Concentration of the dissolved organic carbon ranged between 12-13 mg/l in the river water studied, which value is a few times higher than a range 2 to 10 mg/l which is typically found in rivers and lakes [4].

3.2 Dissolved Radionuclides

The activities of dissolved radionuclides in the rivers Pripyat, Sahan and the lake Glubokoye are shown in Table 1. Strontium-90 and ^{137}Cs were predominant radionuclides there. Strontium-90 was the highest among others in Pripyat and Sahan rivers (^{137}Cs / ^{90}Sr = 0.25-0.14), but in the lake Glubokoye activity of ^{137}Cs was the highest (^{137}Cs / ^{90}Sr = 1.4). Contribution of transuranic nuclides of ^{238}Pu, $^{239+240}Pu$, ^{241}Pu , ^{241}Am and ^{244}Cm to the total dissolved activities in Pripyat, Sahan rivers and Glubokoye lake were 1.3, 1.8 and 0.07 % , respectively . Among the analyzed transuranic nuclides , ^{241}Pu had the largest fraction and ^{244}Cm had the smallest one.

3.3 Dissolved and Suspended ^{137}Cs

Table 2 shows the distribution of ^{137}Cs in river (or lake water) over dissolved and suspended forms. The suspended forms were divided into three size fractions as described in Section 2 (EXPERIMENT). The predominant form (71%) of ^{137}Cs was suspended one in April of 1995 in river Pripyat. In September 1995, at the same location, the dissolved and suspended form of ^{137}Cs were comparable (48 % and 52%, respectively). On the other hand, in the tributaries, Sahan (April, 1995) and Uz (Sept., 1995) rivers, dissolved form of

Table 1 Activity concentration of dissolved radionuclides in river and lake water

(Bq/L)

	Pripyat River (Sept. 23, 1995)		Sahan River (Apr. 2, 1995)		Glubokoye Lake (Sept. 20, 1995)	
Nuclides	Activity	(error, %)*	Activity	(error, %)*	Activity	(error, %)*
^{90}Sr	0.22	(0.5)	1.32	(0.3)	12.3	(0.2)
^{137}Cs	5.43×10^{-2}	(2)	1.01×10^{-1}	(2)	17.0	(19)
^{238}Pu	2.2×10^{-5}	(74)	6.0×10^{-4}	(29)	2.6×10^{-4}	(20)
$^{239,240}Pu$	6.2×10^{-5}	(35)	8.5×10^{-4}	(21)	8.3×10^{-4}	(14)
^{241}Pu	5.5×10^{-3}	(21)	3.2×10^{-2}	(52)	2.4×10^{-2}	(7)
^{241}Am	3.2×10^{-5}	(89)	7.3×10^{-3}	(11)	8.4×10^{-4}	(12)
^{244}Cm	1.2×10^{-5}	(33)	5.8×10^{-5}	(55)	4.7×10^{-5}	(28)

* Figures in parentheses denote counting error in % for measured activities.

Table 2 Concentration of activity of Cs isotopes in river water

(Bq/L)

(Date of collection)	Pripyat River (Apr. 3, 1995)		Pripyat River (Sept. 23, 1995)		Uz River (Sept. 22, 1995)	
Forms	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs
Dissolved	1.76×10^{-2}	4.4×10^{-4}	5.43×10^{-2}	1.5×10^{-3}	1.01×10^{-1}	2.8×10^{-3}
Suspended						
>1 μm	4.53×10^{-2}	1.1×10^{-3}	4.32×10^{-2}	1.1×10^{-3}	1.10×10^{-2}	2.6×10^{-4}
1-0.45μm	-	-	8.5×10^{-4}	-	2.0×10^{-3}	-
0.45-0.20μm	-	-	1.5×10^{-4}	-	4.6×10^{-4}	-

(Date of collection)	Sahan River (Apr. 2, 1995)		Glubokoye Lake (Sept. 20, 1995)	
Forms	^{137}Cs	^{134}Cs	^{137}Cs	^{134}Cs
Dissolved	1.8×10^{-1}	4.9×10^{-3}	1.7×10^{1}	-
Suspended				
>1 μm	3.2×10^{-1}	6.5×10^{-4}	9.2×10^{-1}	2.3×10^{-2}
1-0.45μm	-	-	2.3×10^{-2}	8.9×10^{-4}
0.45-0.20μm	-	-	2.6×10^{-3}	1.1×10^{-3}

^{137}Cs was much greater (85-89 %) than the suspended form. Contributions of the three fractions of suspended forms for the total suspended activities were as follows : > 1μm 98 % , 1 - 0.45 μm 1.7 % , 0.45 μm - 0.20 μm 0.3 % in River Pripyat in September of 1995. These data can be summarized as follows: i) the suspended form of ^{137}Cs in river was most important in the April in river Pripyat, and was comparable to the dissolved form in September . In river Sahan and Uz, dissolved form of ^{137}Cs was more important than the suspended. Concerning about ^{134}Cs, its proportion to ^{137}Cs was almost constant (0.024 - 0.025, decay corrected for the date of the sampling in April and September 1995) for both dissolved and suspended fractions.

4. DISCUSSIONS

4.1 Mobility of radionuclides from soil to river water

In order to quantify the secondary migration of the radionuclides in the soil as a source of contamination of aquatic environment, relative abundance of a radionuclide i to that of ^{137}Cs was assessed for the Sahan river watershed. An index defined as follows was introduced :

$$\text{Mobility index} = \{ [A_i / A_{Cs}]_{\text{river water}} \} / \{ [A_i / A_{Cs}]_{\text{soil}} \}$$

In this comparison, ^{137}Cs was chosen as a standard nuclide because i) it is generally known as one of the least mobile nuclide, ii) it is the major radionuclide in the area, and iii) its analytical error was small. In the Sahan river watershed, a soil core was sampled in September of 1995 in a forest within 0.5 km from the sampling location of river samples in the Sahan river. From the core, lower leaf litter layer and the top soil layer (0-1 cm) beneath the litter layer were analyzed for their activity concentrations. Then the index defined above was evaluated. The derived values of the mobility index are listed in Table 3. The result clearly shows that the relative mobility to ^{137}Cs was highest for ^{90}Sr and lowest for Pu-isotopes. The values for Pu-isotopes fell in a narrow range, suggesting that they behave similarly as identical element. Interesting was high mobility of ^{241}Am. The order of the mobility was as follows:

$$[\,^{238}Pu,\ ^{239+240}Pu,\ ^{241}Pu] < [\,^{137}Cs\,] < [\,^{241}Am\,] << [\,^{90}Sr]$$

The highest mobility of ^{241}Am among the analyzed transuranic nuclides would be an important implication for evaluation of the fate of long-lived radionuclides derived from the Chernobyl accident. Though the above finding on the mobility of radionuclides is consistent with the known characters of the investigated radionuclides, it is just apparent one. A connection between the radionuclides in soil layers and those in river water should be thoroughly studied [5] with considerations for actual transport processes such as movement of soil solution, run-off water, erosion of contaminated soil particles.

Table 3 Comparison of normalized concentration of activity in surface soil and in river water in the Sahan river watershed (normalized to ^{137}Cs, dissolved activity in river water are from Tables 1 and 2)

	Activity in Surface Soil *		Ratio of normalized activity **	
	Activity (Bq/g)		[A(nuclide)/A(^{137}Cs)] water / [A(nuclide)/A(^{137}Cs)] soil	
	In Soil layer		*For Soil layer*	
Nuclides	lowest litter layer	top soil 0-1cml	lowest litter layer	top soil 0-1cm
^{137}Cs	359	20.1	-	-
^{90}Sr	119	5.52	22	27
^{241}Pu	98.7	6.80	0.7	0.5
$^{239,240}Pu$	3.78	0.15	0.4	0.6
^{238}Pu	1.91	0.082	0.6	0.8
^{241}Am	3.01	0.14	4.8	5.8

* The sample was collected on Sept. 18, 1995
** A(i) denotes activity concentration of nuclide i in (Bq/L) and (Bq/g) for water and soil samples, respectively.

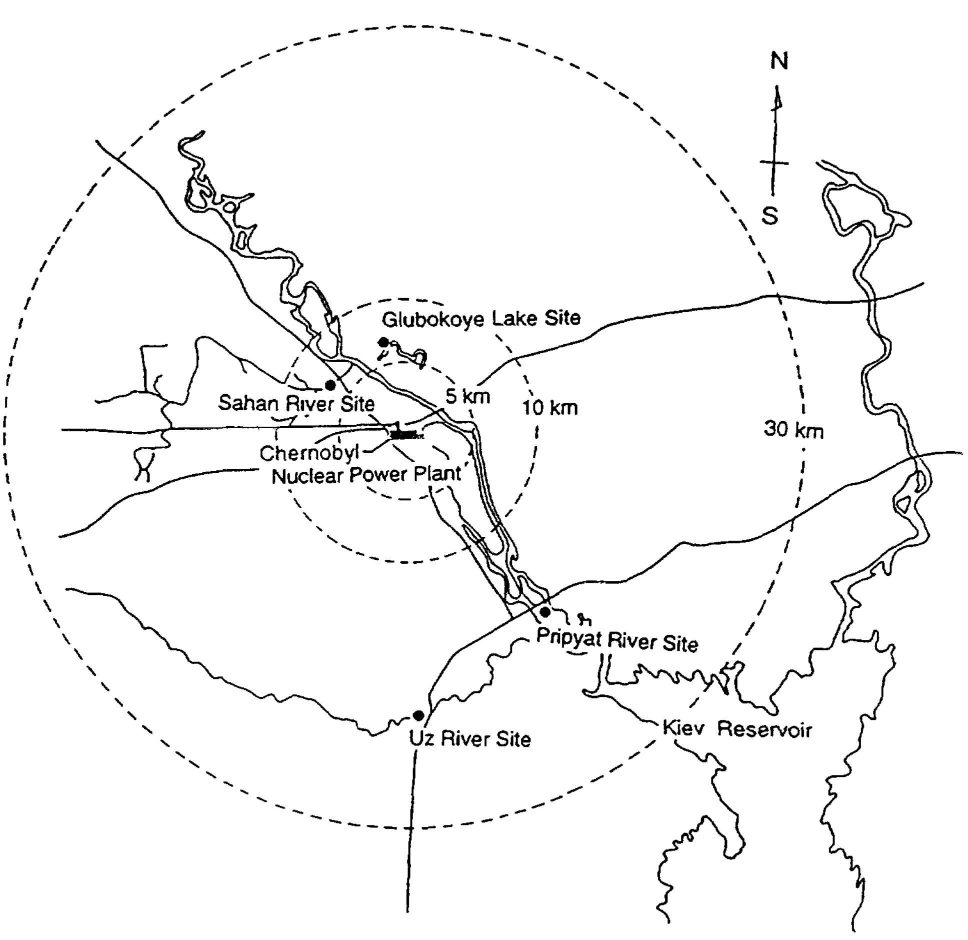

FIGURE CAPTIONS

Fig.1 Locations of sampling sites of river and lake water samples in the exclusion zone of the Chernobyl Nuclear Power Plant. The soil samples from the Sahan river watershed were collected on its left bank near the river water site .

4.2 Phase distribution of Cs isotopes

The present data showed that the distribution of ^{137}Cs varied over dissolved and suspended forms due to differences in sampling occasions and locations. In the concentration of dissolved ^{137}Cs in the river Pripyat, the reason for the lower value in April of 1995 than in September of 1995 would be dilution by water flood due to snow melting. Concerning about the suspended form (> 1μm) , the value in the April was not significantly lower than in the September. It means that there was large input of the suspended form compared to the dissolved form in the April, in spite of the increased water flow. This large input of the suspended form of ^{137}Cs would be from erosion of contaminated, surface soil particles. In Sahan and Uz rivers, the suspended form was not so important as in the Pripyat river. This must be due to lower concentration of suspended solid in the tributaries compared to the main stream.

The present result concerning about the phase distribution of ^{137}Cs indicates that the major controlling factor for the distribution is the concentration of suspended solid in river water, as found in the studies for weapon fallout ^{137}Cs in a river in Japan [1]. Its seasonal and spatial variations are reflected in our present observations.

5. CONCLUSIONS

Composition of radionuclides in river and lake water in the exclusion zone of the Chernobyl area was investigated. The main part of dissolved radioactivities was from ^{90}Sr and ^{137}Cs. The contribution of the transuranic nuclides (^{238}Pu, $^{239+240}Pu$, ^{241}Pu , ^{241}Am and ^{244}Cm) to the total dissolved radioactivities was as small as 0.07 - 1.8 %.

As for ^{137}Cs in water, suspended form of ^{137}Cs was predominant (48-70%) in the Pripyat river, while it was small in the Uz river and the Sahan river. The difference possibly reflects the difference in availability of suspended solid in river water. The component of suspended form greater than 1 μm was found to have a significant role in transportation of ^{137}Cs.

Comparison between the relative activities of radionuclides in the soil and the river water in the Sahan river watershed suggested that apparent mobility of the radionuclides from the soil layer to the river water in the watershed may be in the order of [Pu-isotopes] < [^{137}Cs] < [^{241}Am] << [^{90}Sr].

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ENVIRONMENTAL RADIOACTIVITY IN THE SOIL OF THE REPUBLIC OF KOREA ONE DECADE AFTER THE CHERNOBYL ACCIDENT

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1. INTRODUCTION

During Chernobyl accident a large amount of radionuclides were released into atmosphere and added to atmospheric nuclide inventory from weapons tests. In early May of 1986 in South Korea, radioactivities such as I-131 and Cs-137 were detected in surface air and rain water. That indicated that Chernobyl debris spreaded to far eastern Asia. In the present time, the long-lived radionuclides have been deposited on the soil of Korean peninsular resulted from Chernobyl accident as well as from atmospheric nuclear weapon tests. Meanwhile, it has been reported that isotopic properties in fallout differ significantly, depending on their origin. Several studies have reported that plutonium isotopic ratio, Pu-238 to Pu-239,240 in particular, in fallout originated from Chernobyl accident was quite different from the ratio in global fallout from nuclear tests and burn-up of SNAP-9A satellite using Pu-238 as energy source[1]. As soil, in terrestrial environment, is a principal reservoir of man-made radionuclides, a study on isotopic characteristic in soil can give some information on how Chernobyl accident is effecting on Korean environment.

In this study, the vertical inventory of radionuclides, Pu-238, Pu-239,240 and Cs-137, and their isotopic ratios in soils were investigated to estimate the contribution of Chernobyl derived-nuclides to Korean environment.

2. MATERIAL AND METHODS

Undisturbed soils and ploughed soils were sampled in various soil layers of 20 cm depth in southern part of Korea in fall and winter of 1994 and spring of 1995. The 5 to 10 soil samples in a site were taken with a core sampler(4.5 cm ID) or with a frame(30 cm X 30 cm). For grassland samples, the organic mat layer and the litter layer were included in the top 2 cm samples while the grass and weeds were removed. The fallen leaves or needle were carefully removed from the woodland soil before sampling. The ploughed soil was sampled after harvest.

The soil samples were dried at 110 ℃ and well mixed before radiochemical analysis. Cs-137 was directly determined by gamma spectrometry, using a multichannel analyzer with high purity germanium detector. For the determination of the Pu-238 and Pu-239,240, 100 g of soil samples were ashed at 600 ℃ in muffle furnace to eliminate organic matter. After adding Pu-242 as a tracer, soil samples were digested with HNO_3, HF, and $Al(NO_3)_3$ solution. Plutonium was extracted from the dissolved solution into trioctylphosphine oxide in cyclohexane and back extraction was done using ascorbic acid in HCl-solution. The plutonium was purified using anion exchange column following LaF_3-coprecipitation step. Finally plutonium was electrodeposited from HCl/oxalate solution and measured by alpha-spectrometry with Si-barrier detector. The chemical yields in this analytical procedure were in the range of from 60 to 80 %. The dection limit was 4.3 mBq/kg-dry soil for 86,000 seconds of counting times.

3. RESULTS AND DISCUSSION

The inventory data of plutonium and Cs-137 in 20 cm depth soil were shown in Table I. The deposited activities of Pu-239,240 were estimated in the range of 18.3 to 101.8 Bq m^{-2} with a average value of 50.0(±30.5) Bq m^{-2}. The average inventory of Pu-239,240 is comparable to 58 Bq m^{-2} of north temperate zone(40 - 50° N) estimated in UNSCEAR report[2]. In east Asia, the average deposit in Japanese soil collected in 1980 was estimated to be 55 - 65 Bq m^{-2}, which seem not to be statiscally different to the value of this study, while the observed value in chinese soil of Beijing area sampled in 1990 was lower value(24.6 Bq m^{-2}) than that in this study[3,4]. In Table I the averge inventory of Pu-238 was measured to be 1.5(±0.96) Bq m^{-2}, which is very well agreed with the value of UNSCEAR report and was lower than those reported in Czechoslovakia(1.7 Bq m^{-2}), in Italy(3.3 Bq m^{-2}) and in Ireland(2.69 Bq m^{-2})[5].

The accumulated activity of Cs-137 was measured to be from 738.3 to 3,205.3 Bq m^{-2} with the average value of 1,826.7 Bq m^{-2}. This inventory value is lower than those in Europe effected by Chernobyl accident. The Cs-137 inventory in Japanese soil in 1980 was reported to be distributed in 3,000 - 4,700 Bq m^{-2} which is much higher than those in this study[3]. To describe the difference of the ceseum inventory between two east countries, Korea and Japan, it may be necessary to study on the topographical and geochemical characteristics on soils.

As shown in Table I the soils in woodland accumulated isotopes more than in grassland. It indicated that the fallen leaves may build up the fallout inventory in the nearby soil. The deciduous leaves of the tall tree on the ground increased not only the effective surface area for deposition of fallout but also the amount of humic substance to easily associate with metal ions. The present study showed that the inventory of plutonium and caesium deposited in forest soils is two times greater than in grassland.

Table I. Cumulative depositions and activity ratios of Pu-239,240 and Cs-137 in top-20 cm soil layer at 12 sites in South Korea around the end of 1994.

site #	type of vegetation	cumulative deposition, Bq m^{-2}			activity ratios	
		Pu-239,240	Pu-238	Cs-137	Pu-238/Pu-239,240	Pu-239,240/Cs-137
1	grass	27.7	0.86	1,450.0	0.031	0.019
2	forest	50.5	1.51	2,188.8	0.029	0.023
3	forest	84.1	2.78	2,570.0	0.033	0.032
4	forest	64.4	2.04	2,446.7	0.031	0.026
5	forest	101.8	3.31	3,205.3	0.032	0.031
6	grass	18.3	0.25	868.9	0.013	0.021
7	grass	30.2	1.04	1,274.5	0.03	0.023
8	grass	71.0	1.68	2,462.7	0.028	0.028
9	forest	87.9	2.40	3,086.8	0.028	0.028
10	arable	21.2	0.45	738.3	0.021	0.029
11	grass	20.8	0.75	771.8	0.036	0.027
12	grass	22.9	0.98	856.7	0.043	0.026
	range	18.3 - 101.8	0.25 - 3.31	738.3 - 3205.3	0.013 - 0.043	0.019 - 0.032
	arithmetic mean	50.0	1.50	1,826.7	0.030	0.026

There were no significant differences of the fallout deposition across the central part of Korean peninsular as shown in Fig. 1. The annual precipitation rates in the investigated sites are from 1,000 to 1,300 mm. The most of precipitation in Korea concentrates in summer season. That means that the loss of nuclides by rainwater rolling off on the surface of soil can occurs mostly in summer. In this study there are no evidences of having a correlationship between precipitation and the isotope inventory.

The depth disribution of plutonium activity in top 20 cm soil layer for typical two sites were shown in Fig. 2. The activity of Pu-239,240 decreased nearly exponentially with depth. In case of Cs-137 the similar distribution profiles were observed. In the several sites, the concentration of Pu-239,240 was the highest value in soil layer of 2-4 cm depth as shown in Fig. 2-b. These results may be explained either by the downward migration with rainwater or by the outflowing loss of plutonium in surface soil due to rolling off of rainwater. The contributions of top 10 cm soil layer to the total inventory were more than 85 % for Pu-239,240 and 90 % for Cs-137. The higher percent contribution of Cs-137 in upper layer soil than that of plutonium means that cesium is apparently less mobile than plutonium.

In the Table 1 the inventory ratios of Pu-239,240/Cs-137 in 20 cm depth soil were in the range of 0.019 - 0.032 with a mean value of 0.026($\pm$0.004). This activity ratio showed increasing tendency with soil depth, which may be explained by the downward mobility and the decay scheme of isotopes having different half-lifes. Hence, the activity ratio of Pu-239,240 to Cs-137 in soil samples in 1963, when the most of fallout nuclides originated from atmospheric nuclear test, was measured to be 0.0135[1]. This value can be converted into 0.0265 as the estimated value of 1994 considering decay factor of the isotopes. It means that the nuclide inventory in this investigation originated from nuclear weapon fallout. The ratios of Pu-238 to Pu-239,240 in soil inventory was measured to be 0.013 - 0.036 with the average of 0.030($\pm$0.007). Compared to the ratio of inventory as shown in Fig. 2, the isotopic

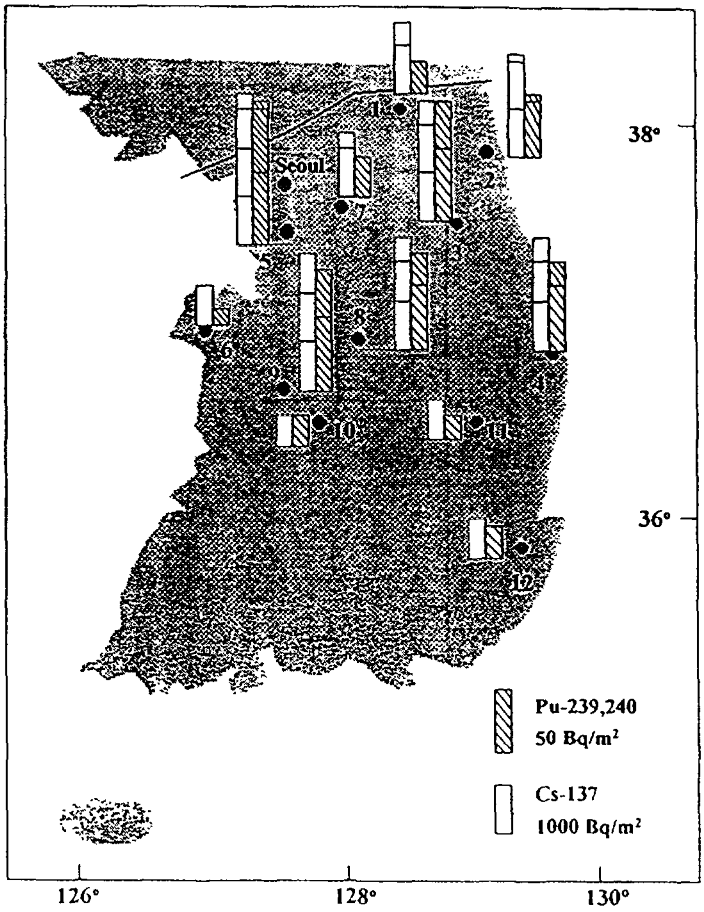

Figure 1. The inventories of Pu-239,240 and Cs-137 in top -20 cm depth soil layer in 12 locations of South Korea.

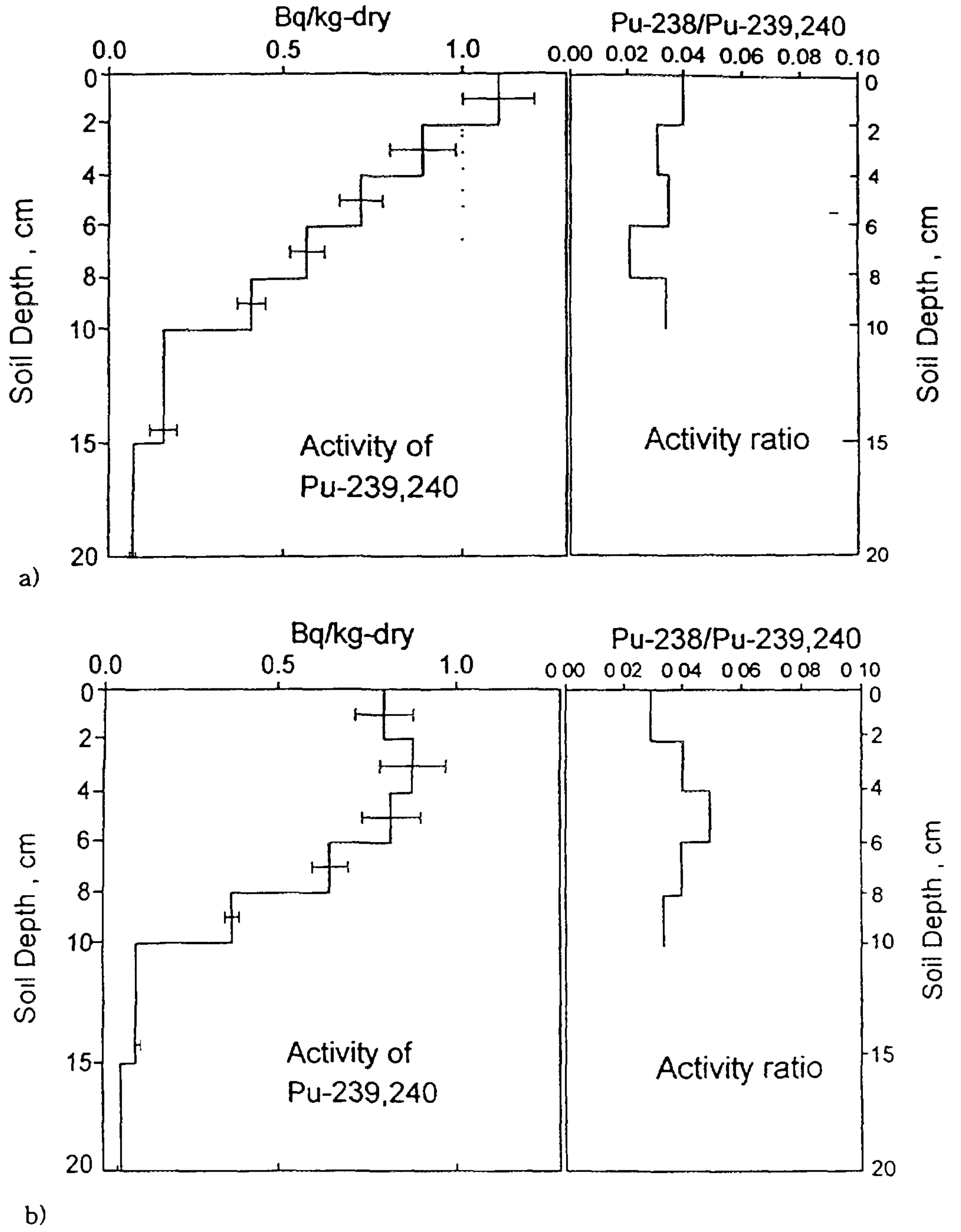

Figure 2 The activity profile of Pu-239,240 and the activity ratios of Pu-238/Pu-239,240 in top-20 cm soil layer, a) for site no 9, b) for site no 3

ratios were relatively constant with depth. It was reported that the plutonium isotopic ratio in global weapon fallout and burn-up of satellite range in 0.02 - 0.09, while around 0 42 in Chernobyl fallout[1] With the plutonium isotopic ratios measured in the present investigation there is no evidence of observable contribution of Chernobyl nuclides to Korean soil at the present time.

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XA9745830

THE CHERNOBYL REACTOR ACCIDENT SOURCE TERM: DEVELOPMENT OF A CONSENSUS VIEW

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I INTRODUCTION

In August 1986, scientists from the former Soviet Union provided the nuclear safety community with an impressively detailed account of what was then known about the Chernobyl accident [1]. This included assessments of the magnitudes, rates, and compositions of radionuclide releases during the ten days following initiation of the accident. A summary report based on the Soviet report, the oral presentations, and the discussions with scientists from various countries was issued by the International Atomic Energy Agency [2] shortly thereafter.

Ten years have elapsed since the reactor accident at Chernobyl. A great deal more data is now available concerning the events, phenomena, and processes that took place. The purpose of this document is to examine what is known about the radioactive materials released during the accident. The accident was peculiar in the sense that radioactive materials were released, at least initially, in an exceptionally energetic plume and were transported far from the reactor site. Release of radioactivity from the plant continued for about ten days.

A number of more recent publications and results from scientists in Russia and elsewhere have significantly improved our understanding of the Chernobyl source term. Because of the special features of the reactor design and the pecularities of the Chernobyl accident, the source term for the Chernobyl accident is of limited applicability of the safety analysis of other types of reactors.

II CORE INVENTORIES

There have been a number of attempts to estimate the radionuclide inventories of the Chernobyl reactor at the time of the accident. Early attempts were handicapped by imprecise knowledge of the fuel burnup in the reactor. Begichev et al. [3] have clarified the burnup history of fuel in the reactor. Their estimate of burnup average is 10 910 MWd/t. Sich [4] has assembled data on samples of core debris remaining in the reactor and concludes that in average the burnup is about 11660 ± 650 MWd/t.

Various estimates of the radionuclide inventories are listed in Table 1. Inventories attributed in this table to Warman [5] were derived from data provided by INSAG [2] which were based on the Soviet report [1]. These estimates have been critically reviewed by Clough [6] and by Devell [7], who noted that typographical errors may be responsible for overestimation of the ^{99}Mo inventory by a factor of 10 and underestimation of the ^{239}Np inventory by a factor of 10. Corrected values are shown parenthetically in the table. Clough provided comparison inventories obtained with the FISPIN code assuming average fuel burnups of 10300 and 13500 MWd/t. He also cited results obtained with the ORIGEN2 code by Anttila [8], who assumed an average burnup of 10000 MWd/t for fuel in seven burnup ranges from 2500 to 17500 MWd/t. Kichner and Noack [9] used the ORIGEN code to obtain inventories for fuel with an average burnup of 12850 MWd/t. Little [10] used the ORIGEN code and an average burnup of 10300 MWd/t to estimate core inventories. Begichev [3] used varying burnups according to reactor operation to obtain estimates of the core inventories of radioactive materials. These burnup histories and the WIMS/CACH2 codes were

Table 1. Estimates of radionuclide inventories at the time of accident initiation. [a)]

Nuclide	Inventory (Bq) by USSR [1] INSAG [2] Warman [5]	Clough [7]	Anttila [8]	Kirchner & Noack [9]	Little [10]	Sich [4]	Begichev et al. [3]
^{85}Kr	3.3E16	--	--	--	2.5E16	2.8E16	3.3E16
^{133}Xe	7.3E18	--	--	--	6.2E18	6.5E18	6.3E18
^{131}I	3.1E18	2.9E18	2.9E18	2.4E18	3.0E18	3.1E18	3.2E18
^{134}Cs	1.9E17	1.1E17	1.6E17	1.4E17	2.0E17	1.7E17	1.8E17
^{136}Cs	--	--	--	9.0E16	9.6E16	6.3E18 (1.1 E17)	--
^{137}Cs	2.9E17	2.4E17	2.2E17	2.7E17	2.3E17	2.6E17	2.8E17
^{132}Te	3.3E18	4.1E18	4.4E18	4.4E18	4.1E18	4.5E18	2.7E18
^{89}Sr	2.3E18	3.6E18	4.0E18	3.2E18	3.0E18	4.0E18	2.3E18
^{90}Sr	2.0E17	2.0E17	1.8E17	2.0E17	1.7E17	2.3E17	2.0E17
^{140}Ba	5.3E18	5.8E18	5.6E18	5.5E18	5.4E18	6.1E18	4.8E18
^{95}Zr	--	5.8E18	--	5.3E18	5.1E18	5.8E18	5.6E18
^{99}Mo	7.3E19 (7.3E18)	5.5E18	5.7E18	--	5.2E18	6.1E18	4.8E18
^{103}Ru	5.0E18	4.3E18	4.0E18	4.6E18	4.5E18	3.8E18	4.8E18
^{106}Ru	2.0E18	8.9E17	7.9E17	1.1E18	1.2E18	8.6E17	2.1E18
^{141}Ce	5.6E18	5.6E18	5.4E18	--	5.1E18	5.6E18	5.6E18
^{144}Ce	3.2E18	3.9E18	3.4E18	3.8E18	3.4E18	3.9E18	3.3E18
^{238}Pu	1.0E15	--	--	7.3E14	1.6E15	1.3E15	1.0E15
^{239}Pu	8.5E14	--	--	8.0E14	9.6E14	9.5E14	8.5E14
^{240}Pu	1.2E15	--	--	1.6E15	1.6E15	1.5E15	1.2E15
^{241}Pu	1.7E17	--	--	1.9E17	1.8E17	1.8E17	1.7E17
^{239}Np	3.6E18 (3.6E19)	4.7E19	5.1E16	6.1E19	6.7E19	5.8E19	2.7E19
^{242}Cm	2.5E16	--	--	3.3E16	3.3E16	4.3E16	2.6E16

[a)] Figures in paranthesis are the final corrected values.

used by Sich [4] to estimate inventories. A corrected value for ^{136}Cs [11] is shown parenthetically in Table 1.

There is general agreement among the various estimates of core inventories shown in Table 1. There are, however, large-enough variations that some caution is needed when inventories are used to calculate release fractions. Estimates of inventories made by Begichev et al. [3] may be the most reliable since they were calculated with the most detailed fuel history. Notable differences between results obtained by Begichev et al. and others are that the ^{132}Te and ^{89}Sr inventories are 30 to 40 percent lower and the ^{106}Ru inventory is 40 to 50 percent higher.

III RELEASE CHARACTERISTICS

The pattern of radioactivity release during the Chernobyl accident has been discussed by many authors [1-5, 12]. There was an initial, intense, release of radioactivity during the dynamic events following the reactivity insertion that started core disruption. This initial release included fragments of fuel as well as other types of aerosol particles, radionuclide vapors and noble gases. Though the released, radioactive material was lofted high above the reactor in an energetic plume, much of the material and especially the fragmented fuel particles, deposited within the borders of the former Soviet Union. Nevertheless, substanstial amount of radioactive material, including material composed of fuel fragments, was carried beyond these borders.

The initial, intense phase of the accident was not the end of radioactivity releases from Chernobyl. Releases of radionuclides continued for several days after the initial core disruption. The rates of radioactive material release declined rapidly after the initial dynamic stage of the accident. A broad minimum in the radioactive material release rate was reached about April 29. Then, radioactive material releases began to increase despite heroic efforts at the reactor site to mitigate and manage the accident. On or about May 5, some 9-10 days after accident initiation, the radioactive material release rates dropped by about 3 orders of magnitude. Release rates that had been on the order of 10^{16} Bq per day fell to an average estimated by Cambrey et al. [13] to be 9 x 10^{11} Bq per day, though there may have been episodic eruptions over the next few weeks [1, 4]. Buzulukov and Dobrynin indicate significant releases of radioactivity occurred 20-21 and 25-30 days after accident initiation [14]. These indications may have been the result of vaporization of dust-suppression solutions admitted to the reactor vault. The releases are thought not to have added greatly to the total radioactivity release from the plant.

Quantitative descriptions of the radioactivity releases during the accident were presented by Soviet scientists in 1986 based on air sampling and surveys of ground contamination within the Soviet Union [1]. Materials that went outside the borders of the Soviet Union were not included.

It has been assumed that the variations in the rates of radioactivity release could be explained by the behaviour of core debris within the reactor. It has long been known that a fairly vigorous natural circulation of air up through the damaged portion of the reactor provided an efficient transport of radionuclides released from the core debris. Further interpretation of the release has been complicated by uncertainties concerning the behaviour of the graphite moderator and the effects of many tons of lead, borax, clay, and sand dropped into the reactor vault to smother the burning graphite.

In recent years, it has been possible to re-enter the reactor, take samples, make measurements, and clarify some of the effects of deposited materials and to determine the fate of the core debris. Sich and Borovoi [4, 15] have published an account of these investigations. More recent investigations have been performed and updated figures of core debris distribution have been presented [16].

The most remarkable feature of the core debris is that some fraction of it melted and dissolved into the serpentine concrete lower biological shield of the reactor. This molten mass flowed into lower portions of the reactor where it froze. Apparently [4], little of the materials dropped from helicopters into the reactor vault actually landed on core debris. Consequently, these efforts at accident management little affected core debris behaviour or the releases of radioactive materials from the reactor.

Another remarkable finding of post-accident inspections of the reactor is that most of the graphite moderator has burned and disappeared. In 1986, it was thought that only about 20 percent of the graphite had burned, though some familiar with the damaged reactor claimed more had burned.

Based on these findings, Sich [4] has developed qualitative hypotheses concerning the behaviour of core debris following the initial dramatic events of the accident. He suggests that initially much of the fuel accumulated as a rubble bed intimately mixed with fragmented moderator graphite in the reactor vault. Combustion of the graphite in the rubble bed allowed fuel to segregate into an uncoolable mass. This mass heated sufficiently to penetrate into the lower biological shield. Eventually, a fairly fluid core debris-concrete mixture was able to flow out of the reactor vault and quench in lower regions of the reactor building. When this happened, radionuclide releases were abruptly reduced. Sharp rises in the radionuclide concentrations above the reactor on May 7-9 and May 16 may indicate core debris relocation events.

It appears that there is now sufficient evidence about core debris behaviour that predictions of the quantitative details of fuel behaviour including predictions of radionuclide release could be formulated. Following the initial, transient events, fuel would have been exposed to rather low oxygen potentials dictated by the equilibrium:

$$O_2 + 2C(solid) \Leftrightarrow 2CO(gas)$$

These conditions would favour the vaporization of radionuclides such as barium and strontium which are most volatile in the elemental state. Transport of vaporized species would be limited by the natural convection flow through a porous, gas-generating bed. As combustion of the graphite progressed, the porosity of the rubble bed would increase and fuel would be exposed to higher oxygen partial pressures. At higher oxygen partial pressures, radionuclides such as ruthenium, molybdenum, and technetium, which are most volatile in the oxidized state, would vaporize. Vaporization of the volatile oxides would become progressively less efficient as fuel segregated from the rubble of the moderator and attacked the biological shield at the base of the reactor vault. Partitioning of metallic fission products such as ruthenium and molybdenum from the fuel into the molten, steel liner of the biological shield would further affect vaporization of these elements.

Exposure of the fuel to high partial pressures of oxygen from the air would be expected to cause oxidation to U_3O_8. Strains produced in solid fuel by this oxidation will cause fracture and decrepitation. This fragmentation of the fuel by oxidation could be responsible for evidence of mechanical release of radionuclides late in the accident.

IV RADIONUCLIDE RELEASES

The fractional releases of individual radionuclides estimated to have occurred over the course of the Chernobyl accident in 1986 are shown in Table 2. The "initial estimate" in this table is that presented in 1986 by Soviet scientists [1]. The "current estimate" listed in the table is mainly adopted from Bedyaev et al [17], supplemented with results and comments by authors of this paper. The release of noble gases (krypton and xenon) was estimated to be 100 percent of the core inventory. The initial release estimates for the volatile radionuclides iodine, tellurium and cesium based on ground contamination in the Soviet Union varied between 10 and 20 percent. About 3 percent of the fuel and associated low volatility radionuclides were estimated to have been dispersed from the reactor building. Barium and strontium were indicated to have been released slightly more than the fuel material.

Initial release estimates shown in Table 2 were based on materials deposited only within the borders of the former Soviet Union. At the time the initial estimates shown in Table 2 were prepared, Soviet scientists did not have access to data on radionuclides deposited in other countries. In the discussion at the Vienna meeting in August 1986 it was accordingly suggested that the total release must be significantly higher.

Warman [5] was among the first to publish revised, quantitative estimates of the Chernobyl reactor accident source term that included materials deposited outside the Soviet Union. Global dispersion codes (PATRIC, MESOS, GRID, ARAC) and compositions of samples obtained in various countries were used to estimate total iodine releases of 40-60 percent [18] of the initial core inventory. Tellurium and cesium releases were estimated to be between 30 and 50 percent of the initial core inventory. Confirmation of estimated releases of fuel and low volatility radionuclides could not be done by this technique since most of these materials deposited within the Soviet Union. A more recent, more comprehensive analysis of the long-range transport of radionuclides outside the former Soviet Union has been published by Gudiksen et al [19]. They conclude release fractions for cesium and iodine were 40 and 60 %, respectively. They estimated the release fraction of tellurium to be only 10 %. Release fractions for other, condensable radionuclides are estimated to be small since most of these materials deposited within the Soviet Union relatively near the reactor site and were not included in their worldwide transport analysis.

Current, best estimate releases of radionuclides from the Chernobyl reactor have been prepared by Bedyaev et al. [17] and are listed in Table 2. The 33 % release fraction of cesium was first announced 1989 by A.A. Borovoi [20]. The cesium release fraction, 33 ± 10 percent, has also been given by Buzulukov and Dobrynin [14] and is consistent with the observed release of 47 percent of the cesium from residual fuel in the reactor and the observed cesium retention within

Table 2. Estimates of Radionuclide Releases During the Chernobyl Accident

Radionuclide	Percent of Core Inventory Released: Initial Estimate [1][(a)]	Percent of Core Inventory Released: Current Estimate[(b)]
^{85}Kr	100	100
^{133}Xe	100	100
^{131}I	20	50-60
^{132}Te	15	10-60 (c)
^{134}Cs	10	33±10
^{137}Cs	13	33±10
^{140}Ba	5.6	3.5-6 (d)
^{95}Zr	3.2	3.5
^{99}Mo	2.3	3.5-6 (e)
^{103}Ru	2.9	3.5-6 (e)
^{106}Ru	2.9	3.5-6 (e)
^{141}Ce	2.3	3.5
^{144}Ce	2.8	3.5
^{89}Sr	4	3.5-4.5 (d)
^{90}Sr	4	3.5-4.5 (d)
^{239}Np	3	3.5
^{238}Pu	3	3.5
^{239}Pu	3	3.5
^{240}Pu	3	3.5
^{241}Pu	3	3.5
^{242}Cm	3	3.5

(a) Based on integration of deposited materials within the borders of the Soviet Union only.
(b) Comments by authors of this paper given in notes c-e.
(c) Air samples above the reactor and in Nordic countries and deposition indicate a release fraction up to 2 times that of cesium.
(d) Selective releases of strontium in addition to releases caused by fuel fragmentation have been detected. The range given for barium doesn't reflect any new results.
(e) Air samples in Nordic countries indicate extensive Mo and Ru release relative to Ce and Zr in the late phase of the accident. From comparison of deposition of Ru with that of Ce as well as that of Cs the total release is estimated to 3.5-6 %.

the damaged reactor [17]. It is also consistent with analyses of the worldwide dispersion of cesium from the accident [5, 19]. Release fractions for iodine have been estimated to be as high as 80 percent, but the most likely range is between 50 and 60 percent. Tellurium release remains uncertain. Air sampling data and deposition in Nordic countries suggest that the release fraction for tellurium could have been up to two times higher than that for cesium [21, 49].

Estimated releases of barium and strontium are judged not be less than the releases estimated for low volatility elements such as cerium and zirconium. Evidence from solubility measurements of particle samples taken at various distances from the Chernobyl site [22] show there was, indeed, some selective release of strontium. On the other hand fuel material released was depleted to some extent in strontium and some other elements. These results indicate a total 3.5 - 4.5 % strontium release [49].

From the earliest days of the Chernobyl accident, it has been known that many of the radioactive particles transported outside the former Soviet Union were nearly pure ruthenium [23]. The appearance of ruthenium particles was unexpected and the mechanism of release has been the subject of discussion [12, 24]. It is likely that ruthenium was released from the fuel as RuO_3 and RuO_4 vapors that condensed to form metallic particles. Kashparov et al. [25] suggest the reducing agents that caused the ruthenium oxides to be converted to ruthenium metal were particles from structural materials in the reactor.

One of the authors of the present report [21, 26] has shown that, indeed, there were two periods of ruthenium release. The first was during the initial phase of the accident when mechanical, rather than chemical, processes were probably responsible for the release of substantial amounts of radionuclides as fine aerosol particles of fragmented fuel. The second phase of ruthenium release occurred several days later when it is possible that fuel was exposed to high oxygen partial pressures to form volatile ruthenium oxides. He argues that overall ruthenium and also molybdenum releases were higher than the release of fuel material because there was a sharp increase in the concentrations of ruthenium and molybdenum relative to concentrations of cerium and zirconium in air samples taken during later stages of radionuclide release [21, 26, 49]. The hypothesis of two phases of ruthenium release is consistent with the results of leaching tests by Kruglov et al. [22] that show there to be two physicochemical forms of ruthenium in particles deposited within the former Soviet Union. The relative abundance of the low solubility physicochemical form of ruthenium, which is presumably ruthenium in fuel fragments, decreases with distance from the Chernobyl site. The magnitudes of ruthenium and molybdenum releases have been estimated [49] to fall in the range 3.5 - 6 %. Only 4 percent of the initial core inventory of ruthenium remains in damaged fuel in the reactor [27], but this could be indicative of both ruthenium release and partitioning of ruthenium into structural metals. Detailed studies of ruthenium particles as well as fuel particles [28] and the depletion of cesium and ruthenium from the latter have been reported [29].

Releases of the low volatility elements such as cerium, zirconium, neptunium and plutonium occured by fuel fragmentation rather than by vaporization. Consequently, the release fractions for these low volatility elements are equal to the fraction of fragmented fuel dispersed from the reactor. As discussed further in the next section, this does not mean releases of the low volatility elements were confined to the initial, energetic, phase of the reactor accident. It appears that mechanical release of fuel fragments persisted throughout much of the accident. Radiochemical analyses of land contamination of ^{144}Ce, which is expected to have vaporized little from the fuel, are interpreted now to indicate 3.5 ± 0.5 % of the reactor fuel was dispersed from the plant as fragments.

V CHEMICAL AND PHYSICAL FORMS

Characterization of a severe accident source term includes description of the chemical forms of vapors and the physical forms of aerosol particles. Attentions to these aspects of the Chernobyl source term have been based on samples of contaminated materials collected far from the reactor. Much attention has been devoted to the chemical form of iodine. The available data [13, 21, 23, 26. 30] show that much of the iodine was in gaseous form (I_2 or CH_3I). The fraction of iodine that was gaseous varied. Devell reported the gaseous fraction of the iodine to be 60 to 80 percent during the two weeks after accident initiation [26]. Winkelmann et al. [30] report that in the later stages of the accident 40 percent of the iodine was associated with aerosol particles, 35 percent was gaseous elemental iodine, and 25 percent was organic iodide. With time, the organic iodide fraction increased. Cambrey et al. [13] found about 75 percent of the iodine that reached the United Kingdom was in gaseous form. There clearly is no close chemical association between cesium and iodine. Data by Georgi et al [31] show there to be an exchange between gaseous iodine and iodine associated with particles. Furthermore, based on the chemical form of ^{132}I produced by decay of ^{132}Te, the time constant for iodine reaction to form organic iodides in the atmosphere is about 1 day [21, 30, 32].

Cesium in the released material from the Chernobyl accident did not remain entirely in a water soluble form. Salbu [33] found that only 35 percent of cesium in water was present as cations. The rest was bound to colloidal particles. Certainly, by the time the radioactive material reached Salbus's location (Norway), cesium was no longer present entirely as CsOH or CsI. This alteration of cesium to an insoluble form as well as the alteration of iodine from a particulate to a gaseous form may have generically applicable implications concerning the consequences of radionuclide dispersal into the environment.

One of the authors [21, 32] has reviewed the state of understanding concerning aerosol particles produced by the Chernobyl accident. Again, much of the published information has come from samples collected in the West or particles collected from ground deposits. As a consequence, there is little known about size distributions, compositions, and the like for particles as they were emitted from the reactor. Particles that have been studied [22, 23, 25, 28-31, 34-45] fall into three classes:

- fuel fragments that contain fission products but have been depleted of volatile species such as iodine, cesium, and ruthenium;
- mono-element (mostly ruthenium) particles; and
- particles of condensed volatile radionuclides including cesium, tellurium and iodine.

Fuel fragments were certainly formed and lofted from the reactor building during the initial, energetic events of Chernobyl accident. Larger fragments (>50 μm) were deposited near the Chernobyl site. Smaller fragments (<20 μm) were carried well beyond the site and even beyond the borders of the former Soviet Union and have been detected in Poland [29], Greece [40], Bulgaria [46], Hungary [47], as well as the Nordic countries [23, 39, 42, 44, 45]. Interestingly, fragments have been found that include carbon which may have come from the reactor moderator [37].

Fragmentation of the fuel may have persisted throughout the accident. Hot particles consisting of fuel fragments have been detected in Greece which was not exposed to the energetic plume formed during the initial phase of the Chernobyl accident [40]. A possible mechanism for fuel fragmentation late in the accident is air oxidation of relatively cool (< 1000°C) fuel. Air oxidation of uranium dioxide to form U_3O_8 is known to cause decrepitation. Fine fuel fragments, depleted in volatile radionuclides but still containing nearly the initial concentrations of low volatility radionuclides such as zirconium and cerium, could have been dispersed by the strong updraft known to have developed through the core. Certainly, Sich [4] notes that the entire Chernobyl site is heavily contaminated with dust particles he attributes to the oxidation and decrepitation of fuel

Kashparov et al. [25] have shown that aerosol particles with a bimodal size distribution are produced when Chernobyl fuel is heated to 673 to 1173 K in air. Size distribution data for these particles can be fit assuming two lognormal distributions with mean diameters of 5.6 μm (s_g=1.21) and 11.4 μm (s_g=1.19). The proportion of fine particles increases with the duration of heating. After about 16 hours of heating, more than 60 percent of the aerosol emissions were found to belong to the smaller size mode.

The test results obtained by Kashparov et al. certainly show that it is possible for fuel fragment release to have continued well after the initial core disruption event at the Chernobyl accident. That is, fuel fragments detected at later times outside the Soviet Union need not have been resuspended fragments produced by the initial energetic events of the accident.

Volatile fission products (cesium, iodine and tellurium) were found in very small particles (0.5 - 1 μm) that have compositions different than fuel. Jost et al. [35] found that iodine was associated with smaller particles than cesium, ruthenium, or tellurium. Georgi et al [31] observed a similar phenomenon.

VI CONCLUSIONS

A consensus is emerging concerning the general features of the Chernobyl accident and the releases of radioactive materials to the environment during this accident. Knowledge of the radioactive releases has advanced considerably since 1986 as a result of further analyses of environment samples taken worldwide as well as the results of further examinations of the destroyed reactor and analyses of core materials.

It can be concluded now that:

- The release of radioactivity extended over more than a week with two pronounced, intense, emission periods. The first intense, emission period was associated with the accident initiation. The second emission period occurred about a week later when damaged reactor fuel may have been exposed to oxidizing conditions. The exact pattern of radioactive material releases between these two intense periods is not known. About 9 or 10 days after accident initiation, releases of radioactivity fell to very low levels.
- There is a better understanding of the total release of radioactivity to the environment. Releases consisted of gases, vapors, aerosols, fragmented and probably reacted fuel. Current best estimates of the release fractions of various isotopes (see Table 2) are somewhat different than previous estimates and may be revised further in the future.
- More than half the initial core inventory of iodine is thought to have been released. As a result of integration of worldwide deposition and analyses of core debris within the reactor, the release of cesium is thought to amount to about one-third the initial core inventory.
- A peculiar feature of the radioactive material release during the Chernobyl accident is the release of a substantial amount (3.5 percent) of the fuel to the environment as fragments. Release of fuel as fragments occurred during both periods of intense release of radioactivity. Release of fuel fragments late in the accident may be the result of core debris oxidation. Low volatility elements such as cerium, zirconium and the actinides were retained in the fuel fragments and no selective release of these elements by vaporization can be detected. Fuel fragments deposited faster and closer to the reactor site than did cesium and iodine but were detected in e.g. Poland, Bulgaria, Hungary, the Nordic countries and Greece.
- Another unexpected feature of radionuclide release during the Chernobyl accident was the appearance of particles composed almost totally of ruthenium isotopes. The probable mechanism for the formation of these particles is the vaporization of ruthenium oxides from the fuel and the subsequent condensation and reduction of the vapors to form metallic particles.
- Air samples indicate that the releases of molybdenum and ruthenium were substantially higher in the late phase of the radionuclide emission period than were releases of fuel fragments which suggests selective release of molybdenum and ruthenium by oxidation to volatile forms.
- The composition and the characteristics of radioactive materials released from the reactor changed during transport due to gravitational settling, wet and dry deposition, decay and chemical transformations. Chemical transformation of released materials such as the formation of gaseous iodine and water-insoluble forms of cesium could have generic implications for the estimation of the consequences of nuclear reactor accidents.

ACKNOWLEDGEMENT

Prof. A.A. Borovoi at the Russian Research Centre, Kurchatov Institute, as well as many colleagues within OECD countries, have given valuable comments and proposed modifications. The authors would like to express their sincere thanks to all of them. The present paper is a shorter but updated version of a report issued by NEA/CSNI [48].

Financial support from the Swedish Nuclear Power Inspectorate is gratefully acknowledged.

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Studsvik Technical Note ES-96/8 (1996)

THE RELATIVE IMPORTANCE OF INTERNAL EXPOSURE AS REGARDS THE ABSORBED DOSE AFTER THE CHERNOBYL ACCIDENT

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Internal exposure

The wholebody content of radioactive caesium (^{134}Cs and ^{137}Cs) has been measured before and in different periods after the Chernobyl accident [4, 6-11] In the case of the deposition in Sweden after the Chernobyl accident the absorbed dose due to the internal exposure from these nuclides constitutes an important – and e g in the sami population the dominating – fraction of the total absorbed dose, which includes as well the contribution from external exposure Based on the measurements of the wholebody content the average contribution to the absorbed dose in the Swedish population appears to be much smaller than that due to the external exposure

According to our measurements [11] this is true also for the contribution to moose hunters and their families - although they belong to those groups where the radiocaesium content in the body is expected to be relatively high The ratio between concentration in the body of ^{137}Cs and its deposition per m^2 in the pertinent moose hunting region varies from 0 7 for men and 0 4 for women [Bq/kg per kBq/m^2] in areas with high deposition, >30 kBq ^{137}Cs per m^2 after the Chernobyl accident to 1 1 (men) and 0 8 (women) in areas with relatively low deposition, < 10 kBq per m^2,

The corresponding ratio for the average over the Swedish population after the Chernobyl accident is 1 4 Bq/kg in the body per kBq/m^2 in the deposition A similar assessment for the situation after the atmospheric nuclear weapons tests yields 0 8 Bq/kg per kBq/m^2 [4] In the 5 regiones obtaining the highest ^{137}Cs fallout by wet deposition in connection with the Chernobyl accident this ratio is 0 7 The calculated dose rate for a constant body burden of 1 Bq/kg is about 0 0023 mSv/year [4]

The effective half-time of Cs-137 whole body content

Pre-Chernobyl results from whole-body measurements of the change with time of the content of ^{137}Cs in the body [4] indicates an effective half-time of 3 1 year in a group assumed to be representative for the ^{137}Cs change in the Swedish population For the northern areas a half-time of about 4 7 year was obtained for a group of samis [4]

The rural population in northern Sweden has a high level of subsistence through meat from reindeer, moose and other game fresh water fish, and berries A study of the distribution of radioactive caesium in northern Sweden 1988-1993 [6] based on measurments on muscle samples from selected medico-legal autopsy cases indicates an effective half time of about 3 7 year there It should be noted that all these assessments of the half-time concern periods within at most the first seven years after the main fallout With regard to the very long residence time and only slow-changing availability for ^{137}Cs in important food-chains of the boreal and sub-alpine ecosystems a longer half-time for the content in the human body may be expected during later periods in these areas

External exposure

Measurements of the external exposure due to the fallout after the Chernobyl accident indicate that – beside changes due to the physiccal half-lives of the nuclides involved– a decreased effectiveness is apparent over the period 1986 - 1988 [2 3] Edvarson [3] concludes that no further decrease occurs after 1988 – with exception for that caused by physical decay Our measurements based on γ-ray spectrometry in various biotopes close to Umeå, Sweden (64°16 N) show that the attenuation of the 662 keV photon associated with decay of ^{137}Cs increases after 1988 at a rate, which indicates a 50% reduction over a time span of about 10 years The photon fluence integrated over all energies, however, is expected to change less than proportional to the decrease in attenuation of the 662 kev photon. Consequently a change in external exposure corresponding to a "half-time" of about 10 year should constitute an upper limit for the rate of decrease of the external exposure, while the insignificant change after 1988 according to the results from Edvarson [3] yields a lower limit.

In areas with predominatly wet deposition the dose (effective dose equivalent) due to external exposure during the first year after the Chernobyl fallout was estimated to be about 0.05 mSv per kBq/m² ^{137}Cs [3]

Expected time dependence for the average internal and external dose to the individual
Internal dose as a time dependent fraction of total absorbed dose, due to the deposition after the Chernobyl accident, is illustrated in fig.1 based on these results. Four cases are considered corresponding to situations in high and low deposition areas respectively under the assumptions of either no further change after 1988 in the external exposure from the remaining ^{137}Cs activity, or a change corresponding to a 50% reduction over a time span of 18 years. The shaded area indicates the probable interval for the actual internal dose fraction, confined by the upper and lover limits established by the various alternatives discussed above

It should be observed that the assessments illustrated in fig. 1 are based on the assumption that the availability of ^{137}Cs over the food-chains is essentially the same over the whole period considered. However, whole-body measurements discussed above give evidence of a decreasing activity content with a half-life in the interval 3.5- 5 year in an "early" phase after fallout – i e. the first seven years There are several indications that this half-life will increase over longer periods. Nevertheless, the fact that the activity content of ^{137}Cs in man decreases on the average faster than what could be explained solely as a consequence of physical decay implies that the assessments in fig. 1 overestimates the relative importance of internal as compared to external dose. *If, for example, in similar estimations is assumed an effective* half-life of 5 year in the body during the first 10 years after the fallout, the upper limit for the internal dose as a fraction of the total will be about 10%

These results based on the measured content of radioactive caesium in the body evidently are strikingly different in comparison to the calculated internal doses – based on consumption patterns for the populations in the Nordic countries and known or assumed concentrations in various food-items [1]– which indicate a general dominance for the internal dose in the total. In the case of Sweden the internal dose calculated according to the latter principle appears to be about ten times higher than that obtained from wholebody measurements representative of the average in the population. The primary causes to this considerable discrepancy between measured and calculated dose levels needs to be further elucidated – not the least due to its relevance for the achievement of a reliable basis for consequence analyses (in terms of collective dose or dose committment), and decision-making

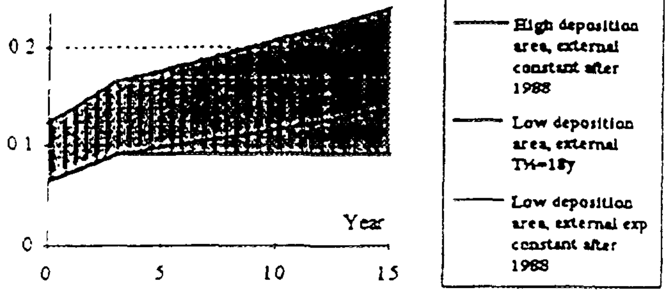

Fig 1 The fraction of the total absorbed dose that is due to the average internal exposure in the general population from radioactive caesium deposited after the Chernobyl accident The time axis refers to time (years) starting from the accident Four alternatives are illustrated corresponding to situations in high and low deposition areas, and under assumptions of either no further decrease in external exposure rate after 1988 – with exception for that due to physical decay – or a further reduction to 50% over 18 years The shaded area covers the interval confined by the upper and lover limits set by these four alternatives

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INTERNAL RADIATION DOSES OF PEOPLE IN FINLAND AFTER THE CHERNOBYL ACCIDENT

XA9745832

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1 INTRODUCTION

After the reactor accident in Chernobyl radionuclides carried by airstreams reached Finland on April 27, 1986 The radioactive cloud spread over central and southern Finland and to a lesser extent over northern Finland In Helsinki the maximum radionuclide concentrations in air were measured in late evening of April 28 The radioactive cloud remained over Finland only a short time and within a few days the radionuclide concentrations in the air decreased to one-hundredth of the maximum values Most radionuclides causing deposition were washed down by local showers, resulting in very uneven deposition of radionuclides on the ground In a addition minor amounts of radioactivity were deposited on May 10-12 [1-3]

The radioactive cloud reached Finland during early spring, when the soil was still partly covered by snow People first became contaminated by inhaling airborne radionuclides Contamination by ingestion later became the only important consideration when radionuclides were transported via various foodchains to man This was important because the growing season had not yet begun or was about to begin during early May and because it was recommended that dairy cattle should not be let out to pasture before May 26 It was also recommended to avoid consuming leafy vegetables grown in the fields More than 30 radionuclides were found in the fallout, with respect to internal contamination the most important were ^{137}Cs, ^{134}Cs, ^{90}Sr and ^{131}I [2,3]

For internal and external dose estimations Finland was divided into five fallout regions (1-5) according to the increasing ^{137}Cs surface activity At first, the short-lived radionuclides as well as ^{134}Cs and ^{137}Cs contributed to the external dose rate Only the long-lived isotopes, ^{134}Cs and especially ^{137}Cs, later determined the external dose rates The regions and corresponding dose rates and deposition categories on October 1, 1987, are shown in Fig 1 [1,3]

To estimate the total dose of the Finnish population from the radionuclides originating at Chernobyl the effective external and internal doses were calculated, the external doses were estimated using the data given in Refs 2-4 Groups of Finnish people representing the five fallout regions were whole-body counted annually during 1986-1990 [5-8] The results of these measurements and those of the reference group were used to estimate the internal body burdens and radiation doses from ^{134}Cs and ^{137}Cs to the population

2 MATERIAL AND METHODS

2.1. Whole-body counters

The radionuclide content in the body was measured using two whole-body counters, IRMA 1 and IRMA 2 [9] The IRMA 1 counter, installed in an iron room, uses a multidetector scanning technique The scanning length is 170 cm and the measurement time usually 30 min The minimum detectable activity (MDA) for ^{134}Cs and ^{137}Cs is about 30 Bq when the nuclides were measured separately and that for ^{131}I about 20 Bq In addition to the total activity, the profile distribution spectra of radionuclides in the body could also be determined

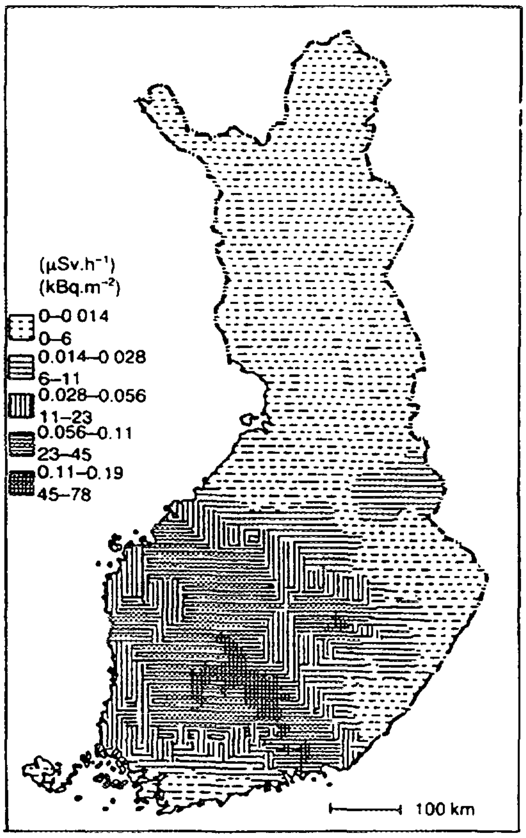

Fig. 1. Distribution of ^{137}Cs (kBq m^{-2}) deposition and external dose rates (μSv h^{-1}) in Finland on October 1, 1987 [1].

The mobile IRMA 2 is a modified chair geometry device with a high-purity germanium detector, and is installed in a lorry. The background shield is made of lead and consists of two pieces: the chair and the detector shield. The measurement time was 1000 s and the MDA for ^{134}Cs, ^{137}Cs and ^{131}I approximately 50 Bq.

Quantitative calibration of the whole-body counters was performed using phantoms filled with known amounts of appropriate radionuclides. The calibration factors as a function of weight of the phantom were calculated separately for each radionuclide. The calibrations were verified by participation in intercomparison and intercalibration exercises [10].

2.2. Population groups measured

Two groups, the Helsinki reference group and the population group, were whole-body counted. The reference group consisting of 26 adults has been measured two to four times annually since 1965 and four times annually since the Chernobyl accident.

In 1986, mainly in May and June, about 160 persons (mostly from the Fallout Region 1) alarmed by the Chernobyl accident were measured. To obtain more comprehensive knowledge of the ^{134}Cs and ^{137}Cs body burdens of the Finnish population, a special study was begun in November 1986, in which 380 persons from different regions of Finland were invited for measurements. These persons were chosen by the Research Institute for Social Security at the Social Insurance Institution using stratified random sampling, the strata being the number of people in the provinces and the sample size self-weighting. Participation was voluntary; approximately half the persons invited attended, of which 96 persons were measured during November and December of 1986 In 1988, an additional sampling consisting of 180 persons from the Helsinki region was performed The Helsinki region was excluded in the first sampling because it belonged to Fallout Region 1, which was already well represented, and because the situation here was well known, as the Helsinki reference group had been whole-body counted since 1965 In 1990 a new sampling consisting of 500 persons from throughout the country was made to ensure that a sufficient number of people could be measured every year. The ages of the measured persons varied 5-65 years and those 5-14 years were classified as children The number of persons measured annually varied from 96 to 323 [5-8]

These people were measured either with the IRMA 1 in Helsinki or with the mobile IRMA 2 in other regions of Finland in connection with measurements of larger local groups Most annual measurements were done during November-April

2.3 Calculation of the mean body burdens of ^{134}Cs and ^{137}Cs

Only people chosen by random sampling were included in the calculations when the mean body burdens of persons residing in different fallout regions were estimated The mean body burdens of ^{137}Cs and ^{134}Cs were calculated separately for children, women and men for each fallout region All results of these subgroups were normalized to the end of the year to enable comparison of body burdens regardless of the time of measurement Normalization was made by assuming that the relative temporal change of individual body burdens in the subgroups followed the mean temporal change of the body burdens which occurred in the Helsinki reference group The mean radiocaesium body burden for a population residing in a certain fallout region was then calculated by weighting the mean body burdens of the subgroups of children, women and men before summation by the relative number of children, women and men in the entire Finnish population. The weighting factor in the calculation for children was 0.195, and it was assumed that the number of adult men and women was equal.

The mean body burden of radiocaesium for the entire population was estimated by summing the regional mean body burdens The regional mean values were multiplied by weighting factors before summing. The relative number of people residing in the respective region was used-as the weighting factor.

3. RESULTS OF WHOLE-BODY COUNTER MEASUREMENTS

The first ^{131}I thyroid contaminations were detected on April 30 but after May 30 no ^{131}I was found. The people reporting for whole-body counting measurements at that time lived in the Helsinki area and represented Fallout Region 1. The results of the whole-body counter measurements indicated that the ^{131}I contamination of thyroid remained below a few hundred becquerels.

The internal contamination of ^{134}Cs and ^{137}Cs originating from the Chernobyl accident could first be detected in the measurements of the reference group in June 1986 Further measurements of this group showed that the body burdens of radiocaesium began to increase and that the maximum body burdens were attained during the summer of 1987 and thereafter began to decline. The respective maximum values expressed as the mean of men and women in the reference group were about 900 Bq ^{134}Cs and 2200 Bq ^{137}Cs. Due to radioactive decay the ^{134}Cs body contents in the reference group decreased to below the detection level in 1994 The temporal variations of mean body contents of ^{134}Cs and ^{137}Cs in the reference group during 1986-1994 are shown in Fig 2

Table I shows the mean body burdens of different subgroups from Fallout Regions 1-5 and the weighted mean values for the entire population in the five fallout regions and throughout the country at the end of 1987 The data in Table I demonstrates the variation in ^{137}Cs levels as a function of ^{137}Cs deposition levels The mean body burden of ^{134}Cs in the entire population group was then about 33% of that of ^{137}Cs During the summer of 1987 the maximum mean values of ^{137}Cs were about 20%

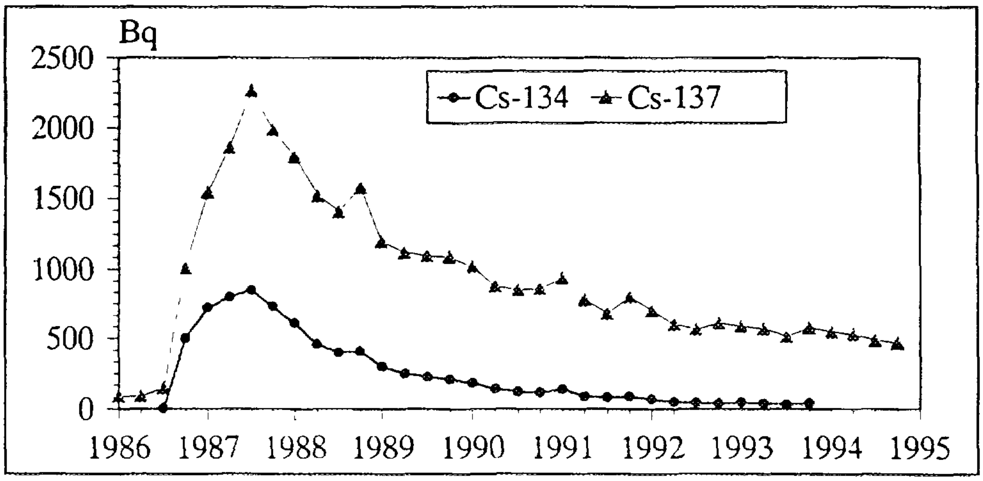

Fig. 2. Variation of body burdens of ^{134}Cs and ^{137}Cs in Helsinki reference group during 1986-1995. The values given are expressed as the mean of the female and male groups (Bq).

Table I. Mean body contents of ^{137}Cs (Bq) in Finnish people at the end of 1987, estimated from whole-body counter measurements of the population group chosen by random sampling.

Group	Fallout region 1	2	3	4	5	Weighted mean for entire country
Men	1700	2100	3400	3900	5400	2800
Women	740	1400	2200	2500	3200	1700
Children	420	660	1300	1400	1400	920
Weighted mean	1100	1600	2500	2800	3700	2000

higher than those given in Table I. In 1987 the highest individual body burdens were 3200 Bq for ^{134}Cs and 9600 for ^{137}Cs and as measured in a male subject from Fallout Region 5. The corresponding maximum values were found in Fallout Region 4 for females (1800 and 5200 Bq) and for children (480 and 1400 Bq), respectively. In general, the individual minimum values in a subgroup were approximately two times less and the maximum values two or more times higher than the mean value of the subgroup.

The mean radiocaesium content of children was about 20-40% and those of women 50-60% of the corresponding values of men. Figure 3 displays the mean body burdens of ^{137}Cs for the entire population group and, for the subgroups representing each of the five fallout regions each at the end of each of the years 1986-1990

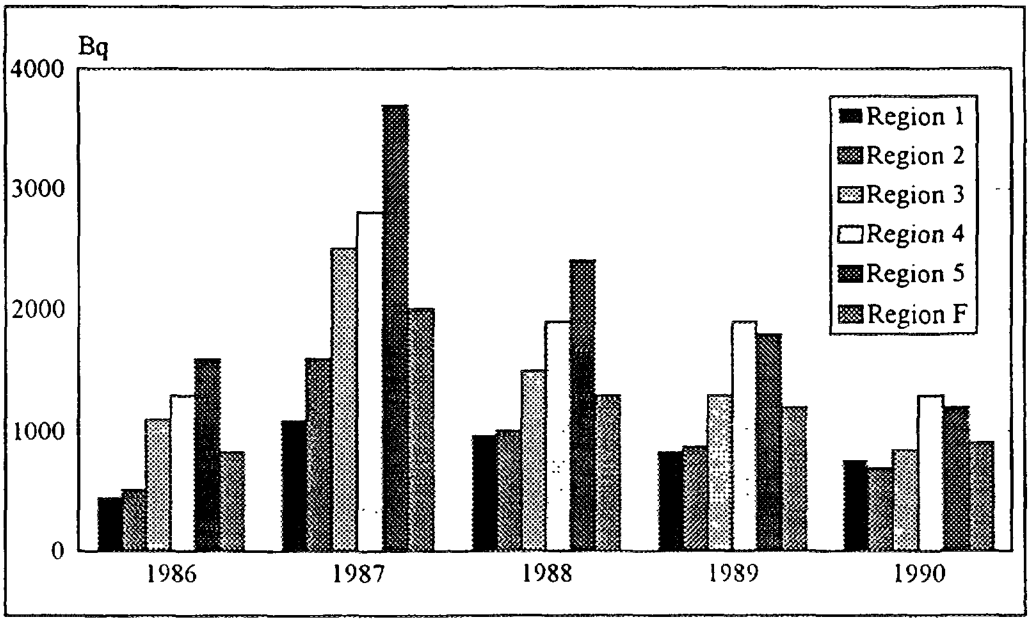

Fig. 3. Mean body burdens of ^{137}Cs for population groups of the five fallout regions (1-5) and the entire country (F) at the end of each of the years 1986-1990.

4. RADIATION DOSES

The internal effective doses from ^{131}I and ^{90}Sr were very small compared to those from radiocaesium. Based on the ^{131}I concentration measurements of milk, the effective total dose was estimated at 0.003 mSv [2]. A rough estimate of the effective dose from inhaled activity might increase the dose from ^{131}I by a few microsieverts. The increase of annual of ^{90}Sr intake after the Chernobyl accident was estimated on the basis of annual countrywide foodstuff surveys [11,12]. The annual effective dose from ^{90}Sr originating from the Chernobyl accident was estimated to be less than one microsievert.

The effective dose for ^{137}Cs was calculated using the dose factor 2.5 x 10^{-6}Sv per (Bq a kg^{-1}) as given in UNSCEAR Report 1988 [13]. The corresponding dose factor used for ^{134}Cs was 3.6 x 10^{-6}Sv per (Bq a kg^{-1}) [6]. The activity time integrals were calculated assuming that the relative temporal change of the individual body burdens (Bq kg^{-1}) in the population subgroups followed the mean temporal change in body burdens which occurred in the Helsinki reference group. The doses were calculated separately for children, women and men. The annual mean doses were calculated using the weighting method described in Section 2.3. The annual mean doses from radiocaesium delivered to the Finnish population were 0.057 mSv in 1986, 0.13 in 1987, 0.086 in 1988, 0.063 in 1989 and 0.044 in 1990. The internal dose calculated from the results of the population group measurements was thus about 0.4 mSv by the end of 1990. The doses of men were highest, while those of children were of the order of 50% and those of women of the order of 70% of the doses of men.

During 1991-1994 it was assumed that the internal doses of the population group changed relatively in the same manner as those of the reference group. The doses after 1994 were calculated using an effective half-life of five years. The half-life was estimated on the basis of the decrease rate of ^{137}Cs body burdens of the reference group after 1990. The observed effective half-life was 4.3 years. The value chosen was thus slightly conservative. Using the dose estimation method described the internal effective dose from radiocaesium for the 10-year period after the Chernobyl accident for the Finnish population was estimated to be 0.52 mSv. The committed effective dose (50 years) from internal radiation from radiocaesium was estimated to be about 0.67 mSv. The estimate also included small contributions from ^{90}Sr and ^{131}I.

The mean external effective dose for the Finnish population was estimated to be 0 10 mSv in 1986, 0 15 in 1987, 0 031 in 1991 and 0 025 in 1994, the doses were based on extensive field measurements [2-4] By use of these values and interpolation, the total external dose during 1986-1990 can be estimated to be 0 4 mSv, which is approximately equal to the internal effective dose By assuming that the external dose rate decreases with a half-life of 21 7 years [2] after 1994 the external dose estimated for the 10-year period after the Chernobyl accident is about 0 54 mSv and that for the 50-year period 1 1 mSv The calculated total dose during the 50-year period after the Chernobyl accident is then 1 8 mSv, of which the internal dose is about 40%

5 DISCUSSION

The radiocaesium levels in the reference group have been monitored since 1965 The measurement results of this group showed that the maximum body burdens of ^{134}Cs and ^{137}Cs were attained during the summer of 1987 The similar behaviour of radiocaesium body burdens could also be deducted from the measurement data of persons belonging to the population group The result is in agreement with expectations when the biological retention and accumulation of radiocaesium in the body and the changes in radiocaesium concentration of the foodstuffs consumed are taken into account Although the mean deposition of ^{137}Cs in the Helsinki area was about 40% of the population-weighted mean deposition of 10 7 $kBqm^{-2}$ for the entire country the mean body content of ^{137}Cs in the reference group was during 1987-90 about 80-100% of that in the entire population group The results of the Helsinki reference group could thus be used to predict internal doses from radiocaesium for the entire population in Finland

The differences in radiocaesium deposition levels in the five fallout regions were reflected in the radiocaesium levels of the measured population subgroups as seen in Fig. 3, as was most clearly seen in 1987 The relationship is not linear, however, which can be seen if the deposition levels (Fig. 1) and the mean body contents of the different subgroups (Table I) are compared Within a certain fallout region, the relative variation in individual body contents of ^{137}Cs is greater than the variation of the ^{137}Cs deposition in that region

One reason for the variation in radiocaesium body burdens is the differences in composition of the diet and the activity concentration of the foodstuffs. The latter reflects the deposition level in the food production area Foodstuffs may be consumed in the area in which they are produced or may be transported and consumed in another fallout region This ensures that the radiocaesium body burdens do not linearly depend on the amounts of radiocaesium deposition and that the variation of the individual radiocaesium body burdens in a certain region is greater than could be expected on the basis of the amount of radiocaesium deposition.

Another explanation for the body burden variations lies in the different amounts of freshwater fish, game, wild mushrooms and berries consumed by people residing in the different regions of the country The activity concentrations of radiocaesium in the wild produce tend to be much higher, and decrease more slowly than those in the agricultural products The intake of radiocaesium from freshwater fish and wild terrestrial produce was approximately equal to that from agricultural products in 1987. Since 1988 the intake from wild produce has been dominant [11,12] Additional variation is caused by the availability of wild terrestrial produce which depends on the from year-to-year variation in meteorological conditions

For economical and practical reasons the number of people measured by whole-body counting was limited On the other hand, the whole-body counter measurements of radionuclides in the body take into account the changes in diet caused by officially recommended or voluntarily taken restrictions of foodstuff consumption with high concentration of radiocaesium In whole-body counting the body burden is determined by the actual intake and metabolic parameters such as biological half-life, which seem to be shorter in the Finnish population [14,15] than the value given in ICRP Publication 67 [16]

The mean internal dose was caused mainly by ^{134}Cs and ^{137}Cs, and the contribution from ^{131}I and ^{90}Sr was negligible, the maximum dose was obtained in 1987 The mean annual internal doses were 10-30% greater than the mean external doses during 1987-1990 Due to the contribution from the short-lived radionuclides, however, the mean external dose was about three times higher than the mean internal dose in 1986 As a result, the total doses from external and internal radiation were each about 0 4 mSv during 1986-1990 When the total dose is calculated for 1986-2036, however, the contribution from the external dose is about 60% and that from the internal dose about 40% The difference is mainly due to differences in the values of the effective half-lives used in the dose predictions Both the internal and external dose predictions may be conservative due to the lengths of the half-lives chosen

In Finland the annual mean total effective dose is 4 mSv from all radiation (natural and artificial) sources The total radiation dose during 50 years following the Chernobyl accident thus represents about half of the dose received annually If the risk factor 0 05 Sv^{-1} given by UNSCEAR is used, the number of fatal cancers among the Finnish population from the radiation dose received during 50 years after the Chernobyl accident would be approximately 450 A more detailed analysis of the risk is presented in Ref 17

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DEPOSITION OF THE RADIOCAESIUM IN SOIL AT THE BLACK SEA COASTAL AREA IN TURKEY AFTER THE CHERNOBYL ACCIDENT

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INTRODUCTION

It was known that some of the Black Sea region received rainfall containing radioactive material after the Chernobyl accident. This region was the most affected area by wet deposition because rainfall occurred during radioactive cloud passage [1]. The unfortunate event at Chernobyl is a unique accasion for better defining the fate of radioactive pollutant in the environment. Several papers have been published recently concerning radioactivity levels observed in part of Europe and Black Sea region as a consequence of the Chernobyl accident [2].

Indeed, the environmental central of Black Sea and its Turkish coast is of particular interest owing to the relative proximity of Turkey to Chernobyl. Not much information for the deposition rates of cesium radionuclides in soil of this area is available.

Exceedingly high Cs-migration rates of 0.2-0.3 $cm.h^{-1}$ in soils were found few days after deposition during a rain shower. However generally the deposited Cs was quickly fixed in the top soil and Cs migration agricultural soils decreased to values below 1 $cm.a^{-1}$, levels which are known from the global fallout cesium [3].

The fallout of radiocesium after the Chernobyl accident has renewed interest in its environmental behaviour. How it behaves in soils is important, for example,for the modelling of radiocesium transport and retention in soil and transfer from soil to plants and hence in to the food chain [4].

MATERIAL and METHOD

Samples were taken from smooth, wide, lawn areas which are at least 100 m away from the dusty roads. The sampling stations were chosen mostly at the meteorological stations. Samples were collected from at least 300 m^2 area. Soil samples were collected from 5 different places in the 300 m^2 area and mixed together to obtain the soil sample representing 300 m^2 of land. Soil samples of the uncultivated areas that received various amounts of rainfall were collected from three different soil depths (0-10), (10-20), (20-30) cm for the analyses of ^{134}Cs and ^{137}Cs. Migration studies in the field are performed best in undisturbed soils [3]. Soil samples were collected from 20 coastal areas and samples were also collected from 6 different interior parts of region to obtain more comprehensive informations. The sampling stations are shown in Fig.1. Stones and roots were removed from the samples by sieving then homogenized by mixing, before the gamma spectrometric analysis. Gamma isotopic analyses were carried out by using high purity Germanium detector connected to standard fast electronics. The resolution (FWHM) was 1.8 keV at

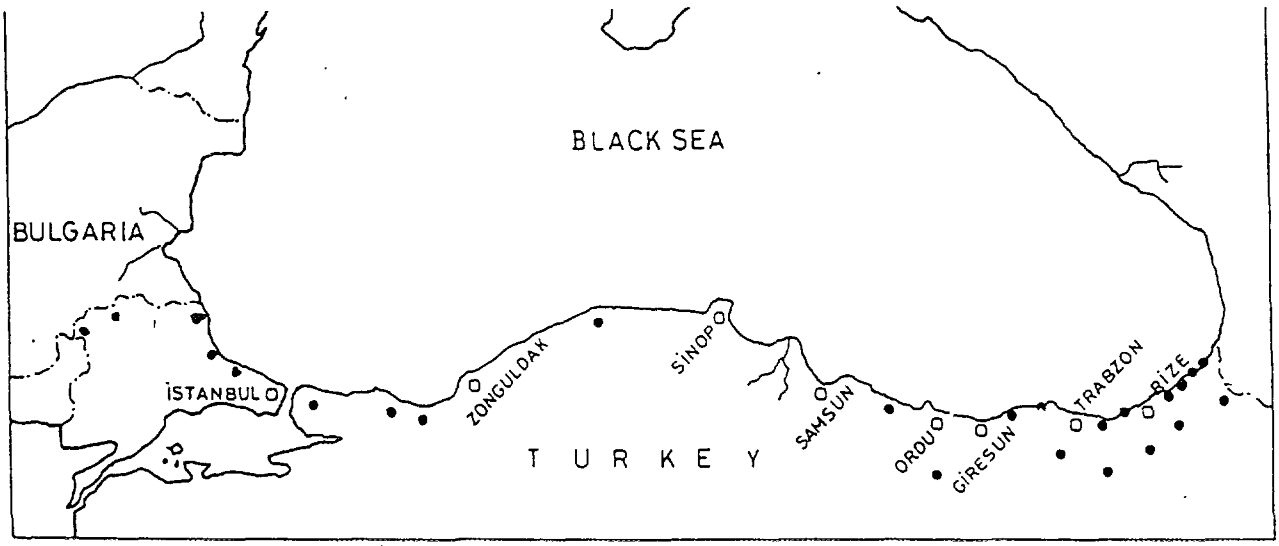

FIG.1. Map of the Black Sea with the locations of the 32 sampling stations.

1.33 MeV. The efficiency and energy calibration of the spectrometer was done with one liter marinelli beaker of gamma Amershams reference source. The peak analysis of all counted samples was made by using Spectran AT software at IBM personal computer. At least 150.000 seconds of counting time was applied to all samples to obtain better statistics, so that the detection limit was about 1 Bq kg^{-1}. All activities were also given after decay correction to the date of the Chernobyl accident. The results (Becquerel kg^{-1} dry soil) are given in Table 1.

pH level, water hold capacity, moisture content, category of soil were determined [5].

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CALCULATION of SOIL ACTIVITY

The variation of the concentration of cesium activity depending on the depth of soil can be well represented by the function, $A(x)=\alpha\exp(-\beta x)$ ---------------------------------(1)
This function is similar to [6]. This function ($e^{-\beta x}$) proposed for block phenomena by Chang. The activity of ^{137}Cs derived from global fallout is the difference between total ^{137}Cs in the sample and Chernobyl- derived ^{137}Cs [7].

The results of spectrometric measurements have indeed proved that this assumption was correct. These kind of figures can also be seen in the literature, [3- 8- 9-10]. The total amount of

TABLE I. CESIUM ACTIVITY LEVELS AT VARIOUS DEPTHS (1.9.1990 Bq/kg DRY WEIGHT), SURFACE ACTIVITY CONCENTRATION OF CESIUM (kBq/M^2) AND PERMEABILITY G

Sampling site	1.Fraction	2.Fraction	3.Fraction	*A°	$G=e^{-B}$	A°
Borçka	31(0.2)	30(0.5)	22(0.5)	11.31	0.969	12.50
Hopa	520(4.8)	29(1.7)	11(2.0)	55.06	0.749	60.83
Arhavi	563(2.0)	134(2.6)	78(1.8)	73.78	0.866	81.51
Fındıklı	1200±5.3	132±2.4	117±3.3	134.79	0.802	148.9
Ç.Hemşin	180±1.4	50±1.5	22±1.4	24.93	0.880	27.55
Pazar	359±1.1	258±1.3	134±1.1	127.73	0.968	141.1
Kalkandere	130±3.8	82±2.6	35±2.8	35.88	0.956	39.64
Rize	509±3.6	115±2.4	36±2.9	65.71	0.862	72.60
Çaykara	124±0.5	66±0.9	64±0.9	26.50	0.939	29.28
Of	335±1.0	32±0.5	19±0.5	37.03	0.791	40.91
Araklı	127±2.1	16±1.3	3±1.2	14.54	0.813	16.07
Maçka	5±0.3	1±0.3	BDL	0.625	0.851	0.691
Trabzon	48±1.7	8±1.2	3±1.5	5.761	0.836	6.366
Eynesil	173±0.4	87±0.8	51±0.6	34.78	0.934	38.43
Tirebolu	289±1.6	11±1.3	8±1.3	30.04	0.721	33.19
Dereli	35±0.2	29±0.5	8±0.3	20.42	0.981	22.56
Giresun	230±0.7	53±0.7	35±0.5	30.24	0.867	33.41
Ordu	89±0.6	23±0.5	16±0.4	12.02	0.874	13.27
Ünye	11±0.3	9±0.4	8±0.4	6.073	0.980	6.710
Samsun	32±0.6	9±0.3	8±0.5	4.450	0.881	4.917
Sinop	34±0.6	3±0.2	2.5±0.2	3.728	0.784	4.119
Inebolu	55±0.7	9±0.4	7.5±0.5	6.576	0.834	7.266
Zonguldak	14±0.5	2.9±0.4	1.8±0.5	1.768	0.854	1.953
Akçakoca	13±0.6	2.5±0.3	BDL	1.594	0.845	1.761
Karasu	11±0.5	1±0.3	BDL	1.210	0.787	1.337
Şile	23±0.6	6±0.5	1±0.4	3.116	0.875	3.443

K.Çekmece	8±0.4	5±0.3	2±0.3	2.130	0.852	2.420
Kilyos	21±0.6	4±0.3	2±0.3	2.570	0.591	2.920
Kıyıkov	16±0.4	13±0.4	3±0.2	8.430	0.884	9.590
Igneada	12±0.4	8±0.5	7±0.4	3.570	0.860	4.050
B.doganca	200±1.1	47±0.7	22±0.5	26.140	0.653	29.730
Kaoıkule	86±0.9	25±0.4	11±0.4	12.100	0.709	13.760

1.Fraction: 0-10 cm, 2.Fraction: 10-20 cm, 3.Fraction: 20-30 cm.
*A^o :$kBqm^{-2}$ (1.9.1990), A^o: $kBqm^{-2}$ (1.5.1986)

activity of each radionuclide deposited per square metre soil surface can be calculated by integrating over all soil layers [3].

A_1, A_2, A_3 being the specific integral activities in the soil arrays of d_o (cm) thickness (Fig.2). The parameters α and β can be obtained by fitting experimental data to the expression (1).

$$\alpha=\beta A_1/\{1-\exp(-10\beta)\} \quad (Bq\ cm^{-1})$$
$$\beta=\{\ln(A_1/A_2)\}/10 \quad (cm^{-1})$$

The total activity per unit area will then be proportional to α/β.

The permeability of soil for radiocesium, we define the expression $G = \exp(-\beta)$ (2) where the parameter β alone is responsible for the dynamics of radiocesium in the soil. In this approximation, the specific effects of organic/ inorganic bounds in the soil and climatic and other effects are not taken into account.

Since d_o= 10 cm, ρ = 1 g cm^{-3} the surface activity concentration can be calculated using the following expression:

$$A^o= 100\alpha/\beta \quad (Bq.m^{-2}). \qquad (3)$$

The results are given in Table I and Fig 3.

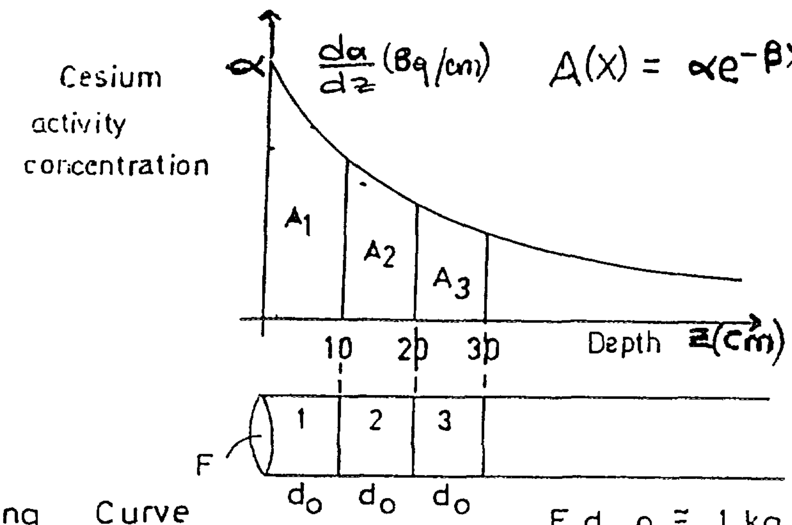

Fig. 2. Modelling Curve

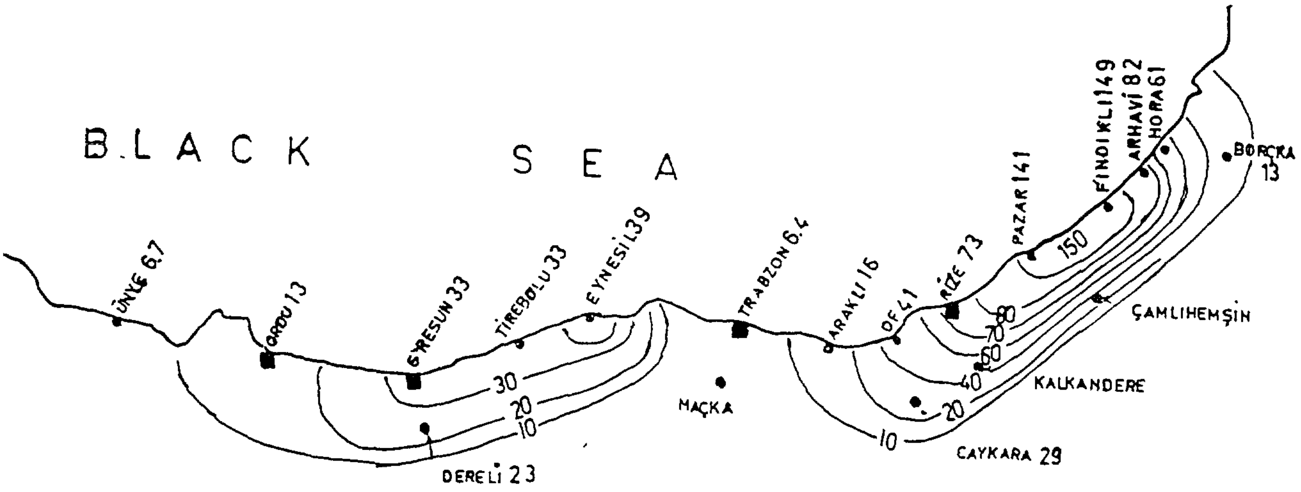

Fig.3 Contour line of Eastern Black Sea (KBq/m^2)

RESULT AND DISCUSSION

The level of the radioactivity is given in Table I. As can be seen from Table I, the activity of ^{137}Cs varied between 5-1200 Bq kg^{-1}. Most of the European Countries has considerably been contaminated after Chernobyl accident [11].. It can also be seen that the Cs activity levels are generally higher in coastal area in eastern Black Sea region compared to the interior sites, because eastern Black Sea mountains are generally parallel to shore. And it can also be seen from Table I that Cs activity levels are related firstly to rain, secondly to category of soil, thirdly to pH levels. Most effective sorption property was belong to clay fraction of the soil [12].

The radionuclides resulting from the Chernobyl nuclear accident contaminated the eastern part of Black Sea including Pazar to Fındıklı mostly and this fact is supported by our finding as activities from the tea [13], hazelnut [14], lichens [15], moss [16] and sediment [17] production of the year 1986. Also the soil radioactivity of the eastern Black Sea region was higher than the other parts of Turkey [1-18].

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XA9745834

IN SITU GAMMA SPECTROMETRY MEASUREMENTS IN HUNGARY DURING THE PERIOD OF 1987-1995

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1. Introduction

In situ gamma-ray spectrometry is useful to obtain mean values for the radioactivity of the soil over large areas and to determine the contribution of individual isotopes to the external exposure rate. The rapidity with which field measurements can be made may be one of the most important factor in emergency planning

During the Chernobyl accident there were only two portable gamma spectrometers in Hungary to perform field measurements. The Environmental Laboratory of NPP Paks and the Central Research Institute for Physics made *in situ* measurements in the vicinity of Paks and at different sites situated mostly in the northern and western part of the country. [1], [2]

The third *in situ* survey was carried out by NRIRR in 1987.

2. Method

In accordance with the procedure outlined by Beck *et. al.* [3], two CANBERRA HPGe detectors (type 7229P MAC, relative efficiency 15 %, FWHM 1.7 keV and type GC 3020 BIGMAC, rel. eff. 30 %, FWHM 2.0 keV) were calibrated with different point sources.

Spectra collected in the energy range of 60-2700 keV with SERIES 10 and PORTABLE PLUS MCAs were evaluated by SAMPO 90 software (CANBERRA). The detector was placed in the field upside-down 1 m above the ground surface and observed an area of diameter 30 m. Time of the field measurements was 5000-20000 s long.

For radionuclide distribution in soil the following was assumed:

(i) a typical soil composition (67.5 % SiO_2, 13.5 % Al_2O_3, 4.5 % Fe_2O_3, 4.5 CO_2, 10 H_2O and density 1.6 g cm^{-3}) [3],

(ii) a homogeneous distribution for natural isotopes and ^{137}Cs originated from the nuclear weapon tests,

(iii) an exponential decrease in concentration with increasing soil depth for nuclides resulting from the Chernobyl fallout. We assumed the relaxation length increasing in time with the rate of 0.5 cm/y.

In situ gamma spectrometry measurements were completed with direct dose rate measurements performed at the same time by a high pressure ionization chamber (type RSS-111 HPIC, REUTER STOKES Instr.) and - at some places - with core sampling. The soil samples originated from layers down to 30 cm depth were analysed by the same gamma spectrometry systems.

3. Results

The *in situ* measurements were performed at 50 different sites listed in Figure 1. Activity concentrations for ^{134}Cs and ^{137}Cs with total exposure rates (estimated from field gamma spectrometry measurements and compared with HPIC data) are given in Table I.

4. Conclusions

These results completed the contamination map given by the first investigations performed in the early part of the accident. The highest deposition was found in the western part of the country (vicinity of

Figure 1 Sites of *in situ* gamma spectrometry measurements in Hungary performed by NRIRR during the period of 1987-1995

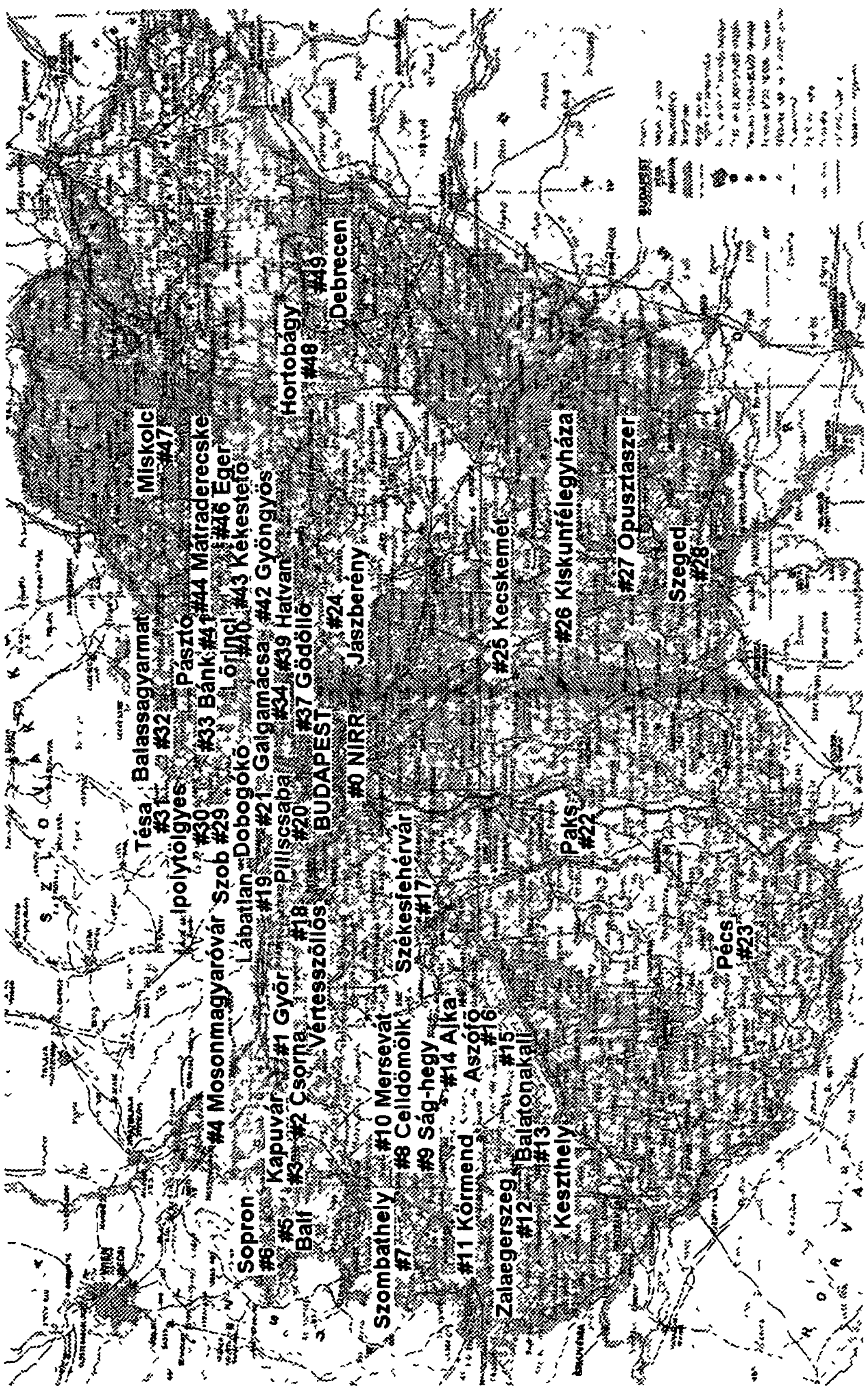

Table I. Activity concentration in soil for ^{134}Cs, ^{137}Cs and total exposure rates (natural + artificial + cosmic) at 1 m above the ground surface

#	Location	Latitude	Longitude	Date	Activity concentration		*Exposure rate*	
		[deg]			Cs-134	Cs-137	*in situ*	*HPIC*
					[kBq m^{-2}]		*[nGy h^{-1}]*	
0	Budapest	47.59	18.95	08 Oct 87	1.89	5.28	*90.7*	*104.0*
1	Gyõr	47.72	17.68	10 Oct 90	0.85	7.15	*82.7*	*85.6*
2	Csorna	47.63	17.25	10 Oct 90	1.43	10.7	*107.0*	*101.7*
3	Kapuvár	47.61	17.03	07 Oct 87	2.51	7.08	*102.7*	*131.7*
4	Mosonmagyaróvár	47.86	17.25	07 Oct 87	2.09	6.80	*107.1*	*120.6*
5	Balf	47.66	16.67	10 Oct 90	1.24	8.94	*97.9*	*95.1*
6	Sopron	47.68	16.58	10 Oct 90	0.65	4.77	*80.6*	*94.4*
7	Szombathely	47.27	16.63	01 Apr 89	1.36	6.57	*115.4*	*127.4*
8	Celldömölk	47.27	17.15	15 Oct 91	0.50	6.03	*85.2*	*100.6*
9	Ság-hegy	47.23	17.10	14 Oct 91	2.43	24.5	*91.3*	*99.7*
10	Mersevát	47.29	17.20	15 Oct 91	0.68	8.35	*80.7*	*87.9*
11	Körmend	47.04	16.57	01 Apr 89	0.59	3.23	*92.8*	*114.3*
12	Zalaegerszeg	46.87	16.80	01 Apr 89	0.90	4.05	*96.9*	*105.4*
13	Keszthely	46.75	17.23	20 Apr 88	1.14	4.13	*88.1*	-
14	Ajka	47.13	17.53	25 Jul 89	0.78	4.72	*92.3*	*99.3*
15	Balatonakali	46.89	17.73	20 Apr 88	0.83	3.54	*77.4*	-
16	Aszófõ	46.94	17.82	04 Feb 88	0.88	3.48	*64.6*	-
17	Székesfehérvár	47.18	18.47	09 Nov 89	0.96	4.58	*93.7*	*102.8*
18	Vértesszõllõs	47.61	18.38	04 Oct 89	0.38	2.95	*71.8*	*85.9*
19	Lábatlan	47.74	18.49	04 Oct 89	1.07	6.19	*86.2*	*96.3*
20	Piliscsaba	47.63	18.82	08 Jan 88	1.23	4.83	*79.0*	*99.9*
21	Dobogókõ	47.72	18.89	18 Feb 88	1.66	6.82	*86.3*	-
22	Paks	46.60	18.84	27 Jan 88	0.40	2.10	*65.7*	*80.0*
23	Pécs	46.00	18.23	08 Aug 89	0.11	1.17	*100.1*	*126.9*
24	Jászberény	47.53	19.90	25 Feb 88	0.63	2.38	*84.6*	*91.4*
25	Kecskemét	46.91	19.75	27 Apr 88	0.43	1.84	*64.0*	*81.6*
26	Kiskunfélegyháza	46.69	19.85	27 Apr 88	-	0.52	-	-
27	Ópusztaszer	46.49	20.08	27 Apr 88	0.91	3.68	*68.0*	*78.0*
28	Szeged	46.26	20.09	27 Apr 88	0.25	1.11	*93.0*	*98.1*
29	Szob	47.82	18.86	03 Oct 89	0.33	2.04	*83.2*	*93.7*
30	Ipolytölgyes	47.91	18.77	03 Oct 89	0.35	2.35	*85.3*	*95.9*
31	Tésa	48.04	18.83	03 Oct 89	0.43	3.25	*91.4*	*95.1*
32	Balassagyarmat	48.08	19.28	03 Oct 89	0.22	2.01	*77.8*	*86.8*
33	Bánk	47.91	19.18	03 Oct 89	0.31	2.10	*76.8*	*87.9*
34	Galgamácsa	47.69	19.39	29 Apr 88	2.33	8.45	*106.7*	-
35	Domony	47.66	19.43	29 Apr 88	1.35	4.62	*101.9*	*116.2*
36	Szada	47.63	19.31	26 Oct 88	1.93	9.22	*86.9*	-
37	Gödöllõ	47.33	19.33	17 Oct 90	1.07	8.37	*87.8*	*82.6*
38	Vácszentlászló	47.57	19.54	05 Nov 87	2.02	6.10	*94.3*	-
39	Hatvan	47.66	19.71	22 Nov 89	1.65	9.69	*96.3*	-
40	Lõrinci	47.74	19.68	16 Oct 90	0.87	7.26	*97.9*	*92.6*
41	Pásztó	47.91	19.71	16 Oct 90	1.18	8.73	*87.9*	*81.3*
42	Gyöngyös	47.76	19.90	06 Oct 87	1.49	4.78	*99.0*	*118.1*
43	Kékestetõ	47.87	20.02	16 Oct 90	0.35	3.69	*78.7*	*85.7*
44	Mátraderecske	47.95	20.07	10 Feb 92	-	1.73	*89.2*	*94.5*
45	Kompolt	47.74	20.20	06 Oct 87	1.65	5.36	*103.0*	*124.6*
46	Eger	47.93	20.34	22 Nov 89	0.37	2.24	*96.4*	-
47	Miskolc	48.10	20.77	22 Nov 89	0.17	1.42	*89.4*	-
48	Hortobágy	47.60	21.15	22 Jan 88	0.47	2.08	*102.0*	*108.4*
49	Debrecen	47.50	21.63	22 Jan 88	0.36	2.12	*88.8*	*86.3*

towns Győr (#1-3), Sopron (#5-6), Celldomolk (#8-10)) and near to the capital Budapest (#0) (towns Godollõ, Hatvan (#34-39) Total exposure rates estimated from *in situ* gamma spectrometry measurements were 15-20 % lower than the values obtained by HPIC measurements

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XA9745835

CAESIUM TRANSFER TO PLACENTA, URINE AND HUMAN MILK

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1. INTRODUCTION

After the Chernobyl accident few measurements on radioactive contamination of maternal milk, placenta and urine of nursing mothers were carried out. Two previous studies on breast milk contamination were conducted in different Italian areas [1,2] by the Physics Department of the National Institute of Health (Laboratorio di Fisica, Istituto Superiore di Sanità).

In the first study[1], conducted in collaboration with the Epidemiological Unit of the Lazio District, I-131, Cs-134 and Cs-137 concentrations were measured in mixed breast milk samples pooled from 5-10 women in the first week after delivery, from May 1986 to December 1987, in the Rome area.

The second research was conducted, in collaboration with the Lecco Hospital, in 1989 on a group of women living in the Como Lake area (Lombardia), which was one of the areas of Northern Italy most heavily affected by Chernobyl fallout, because of intensive rainfall in the first few days after the accident. The specific diet and caesium content in maternal milk[2] were studied recruiting pregnant women at the "respiratory autogen training" course.

In this case, Cs-137, Cs-134 and K-40 concentration in placenta and urine of the mothers under study had also been measured. Aim of this paper is to discuss these data and investigate the relationship between Cs-137 contamination of maternal milk, placenta and urine as a contribution to a better understanding of caesium metabolism in pregnant and nursing women.

2. MATERIALS AND METHODS

Twenty seven women, mean age 29, who delivered at term of gestation, have been recruited in the study. They were interviewed by a physician and a nurse and followed personally by the same nurse till the end of the milk collection. Their diet was investigated both by personal interviews and special personal diaries of their consumption[2]. At delivery their placenta was kept and during puerperium a urine sample was taken from a 24 h collection in day 3 after delivery (unluckily the information about the total volume of the 24 h collection was lost). Finally each mother had to collect 15-20 ml of mature milk from the 10^{th} to the 40^{th} day after delivery, in order to get samples of about 450 ml. All milk, urine and placenta samples were measured in Marinelli geometry with two high purity germanium detectors (26% and 38% of efficiency). They were shielded by 10 cm of lead and had been calibrated with an Amersham calibration source QCY44 (ρ=1 g/cm^3). The background of the systems was measured repeatedly over long periods and subtracted from the spectra. The measurement duration was chosen in order to have the statistical uncertainty on the Cs-137 peak equal to about 5%.

The milk samples (450 ml) and urine samples (1 liter) were measured without previous treatments, whereas the placentae were blended in order to be put in the Marinelli beaker. They had a weight between 250 and 430 g and a volume lower than 450 ml. Therefore, in order to use the same calibration geometry and density, double distilled water was added and mixed, after having checked its radioactive background. The samples so obtained had a mean density equal to 1.04 ± 0.10 g cm^{-3}.

3. RESULTS

From the group of 27 mothers participating in the study, 21 complete cases are available, because a hypogalactic condition arose in 6 mothers, not allowing the milk collection. However, the placenta and the urine samples of these 6 mothers were nevertheless kept and mother's and infant's personal data together with food consumption data had previously been collected.

Concentrations of Cs-137 and K-40 were assessed in all the biological samples. Cs-134 was detected only in a certain number of samples and the ratio of its concentration to the Cs-137 concentration was in good agreement with that detected in Europe in May 1986, taking into account the relevant half-lives.

In the previous study[2] the mean value of daily Cs-137 diet intake was calculated by using the mean daily diet for each mother and the Cs-137 food concentration in the Como area; it resulted equal to about 2.1 Bq/d and the largest contribution came from meat. The Cs-137 transfer factor from woman's diet to maternal milk was evaluated both by using a simplified milk compartment model and as the ratio of Cs-137 concentration in milk to the daily intake. The two values - almost coincident - are comparable with that obtained in the first study[1] and with those available in the literature, which are in the range 0.1-0.3 [3].

In figures 1 and 2 the Cs-137 and K-40 concentrations in 21 maternal milk, 27 placenta and 27 urine samples are shown. The uncertainties on the measurements (one standard deviation) are from 2 to 10% for Cs-137 and 1-6% for K-40.

The data of the 21 women and 21 newborns of the complete study are the following. Mean age at delivery was 28.3 years (SD 2.8; range 25-34); all pregnancies were at term, with mean gestational age 40 weeks (SD 1.5); 17 were primiparae and 4 multiparae with previous positive breast-feeding experience. One mother out of 21 underwent caesarian section. The mean weight of the newborn was 3303 g (SD 441). The mean body mass index (Quetelet's index) of the mothers was 0.21 (range 0.18 - 0.27).

In table 1 the mean values and ranges of the Cs-137 and K-40 concentrations and their ratios are summarized for the three types of biological samples from the 21 women of the complete study.

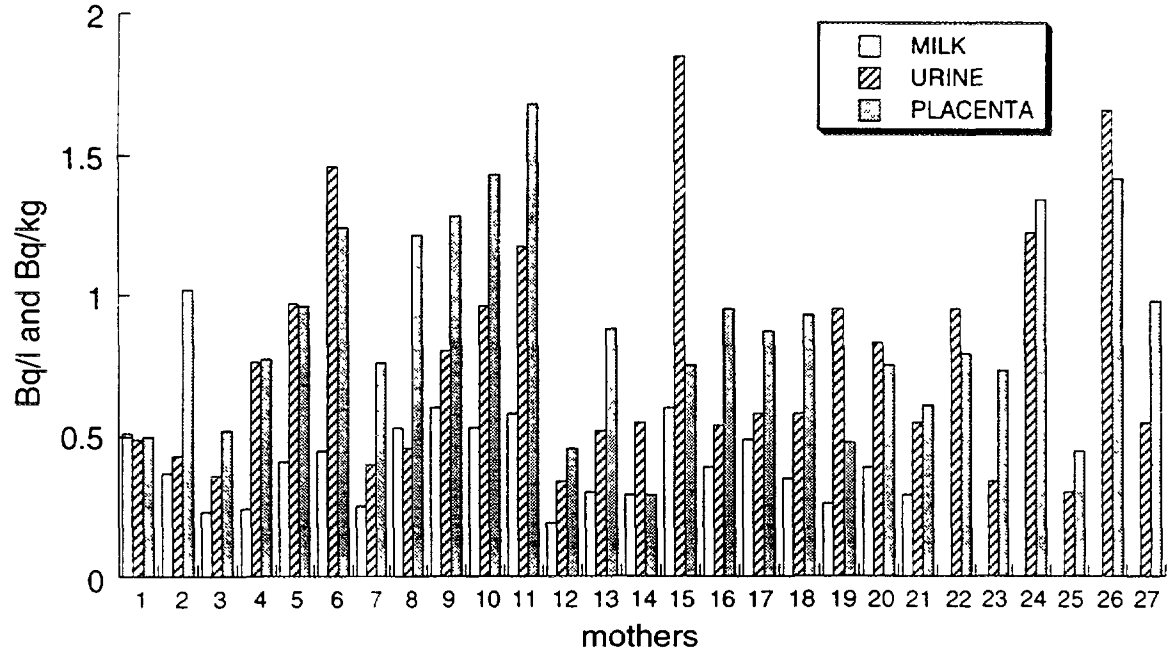

Figure 1. Cs-137 concentration in 21 samples of maternal milk and 27 samples of placenta and urine.

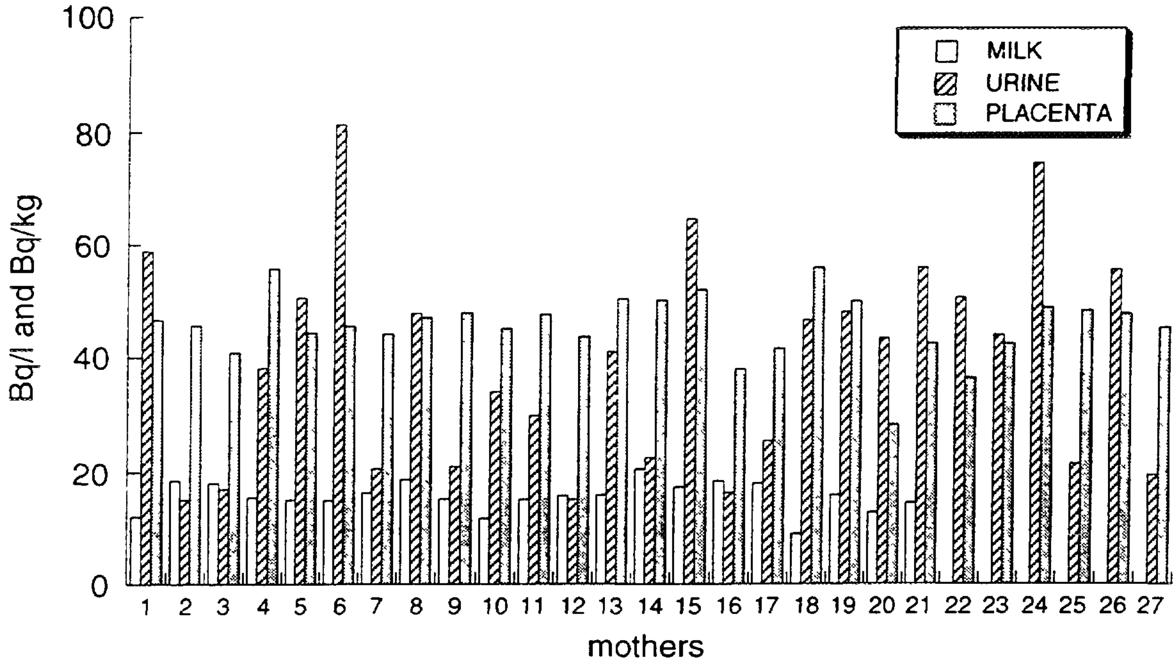

Figure 2. K-40 concentration in 21 samples of maternal milk and 27 samples of placenta and urine.

Table 1. Cs-137 and K-40 concentration and their ratio in maternal milk, placenta and urine for the 21 mothers.

	average	standard deviation	range
^{137}Cs in maternal milk (Bq/l)	0.39	0.13	0.19-0.60
^{40}K in maternal milk (Bq/l)	15.7	2.7	9.0-20.6
^{137}Cs / ^{40}K in maternal milk	0.026	0.011	0.012-0.045
^{137}Cs in placenta (Bq/kg)	0.87	0.35	0.29-1.68
^{40}K in placenta (Bq/kg)	45 9	6 1	28.3-55.9
$^{137}Cs/^{40}K$ in placenta	0.019	0.008	0.006-0.035
^{137}Cs in urine (Bq/l)	0.74	0.38	0.34-1.85
^{40}K in urine (Bq/l)	37.7	18.5	15.0-81.2
$^{137}Cs/^{40}K$ in urine	0.022	0.009	0.008-0.039

The interest in measuring K-40 is connected to the fact that potassium is present in all biological tissues and fluids and - due to its remarkable constant concentration in most of them and to its chemical similarity with caesium - particularly in the past it has been used in studying caesium transfer from the environment to the human body (e.g. from diet to maternal milk[4]). In addition, the constant isotopic abundace of K-40 in potassium makes possible the use of its concentration instead of the total potassium one[1].

The K-40 concentration in maternal milk in the table shows a low variability in comparison with that of Cs-137. This result is confirmed by data in the literature: as a general rule, mothers supply a steady potassium content (the same is true for other substances) whatever their feeding is, even when they are seriously undernourished.

Data from placenta samples also indicate a rather steady potassium content, whereas variability increases for caesium. This is not surprising, as the potassium content of a body organ is only partially related to the intake of this element, and complex metabolic mechanisms from intake to excretion help stabilizing potassium content in human body. On the contrary, the content of caesium in body organs is more dependent on its intake and on body content.

As to urine samples, interpreting data is more difficult. First, it would have been necessary to adjust potassium concentration for daily diuresis. Indeed, it is possible that individuals whose diuresis is higher should have less potassium concentration over the same total excretion; second, a high variability is not incredible, because urinary excretion of potassium is the most important way for the human body to stabilize potassium content when intake varies. Moreover, in order to better understand the real change in potassium excretion, it would be necessary to adjust the value of potassium urinary excretion over that of creatine urine excretion in the same individual (that is a relevant element for kidney functioning).

The correlation between values of Cs-137 concentrations measured in maternal milk, placenta and urine has been studied by using a linear regression, in order to verify if a simple law can be established between Cs-137 in these biological samples.

Data available in literature (see e.g. the review in [5]) show that caesium is distributed uniformely in the body, therefore Cs content of placenta could be an estimate of the total body content, once ascertained - as in this case - that the placentae come from healthy women with a physiological pregnancy and with no alteration of the placenta's flux, a possible cause of differences in caesium concentrations.

Moreover, it would be of the utmost importance to ascertain the existence of a linear correlation between Cs-137 content in mothers' milk and in urines. In fact, if this simple correlation is confirmed, the advantage of the urine samples analysis could be represented by the possibility of undertaking rapid surveys on large groups of nursing women and obtaining information about Cs-137 radiocontamination of maternal milk.

In Fig. 3 the Cs-137 concentrations in placenta versus corresponding values in maternal milk are reported. The regression line was obtained with a preliminary statistical analysis of the data, without taking into account the uncertainties of Cs-137 concentration in milk and therefore treating it as the independent variable. With this hypothesis the correlation coefficient results to be equal to 0.7 ($p=0.0004$). On the other hand treating Cs-137 concentration in placenta as the independent variable the correlation results weaker ($r=0.58$; $p=0.0063$). It is obvious that the assumption of treating one of the two magnitudes as without uncertainty underestimates the uncertainty on the correlation parameters; however, in the limit of this preliminary analysis of the data a rough linear dependence between the two Cs-137 concentration seems to come out.

In Fig.4, the Cs-137 concentrations in milk versus corresponding values in urine are reported, with the regression line. In this case the correlation coefficient results to be equal to 0.56 ($p=0.008$). Exchanging the two variables, r results to be 0.54 ($p=0.011$). However, in this case the scarse correlation between urine and milk values could partially be ascribed to potassium variability in urines. Thus, an eventual deepening of this study should aim at measuring creatine content in urine samples (which have been kept and are still frozen), in order to better understand the problem. Moreover, another type of correlation can be hypothesized between the two magnitudes and will be verified in a future.

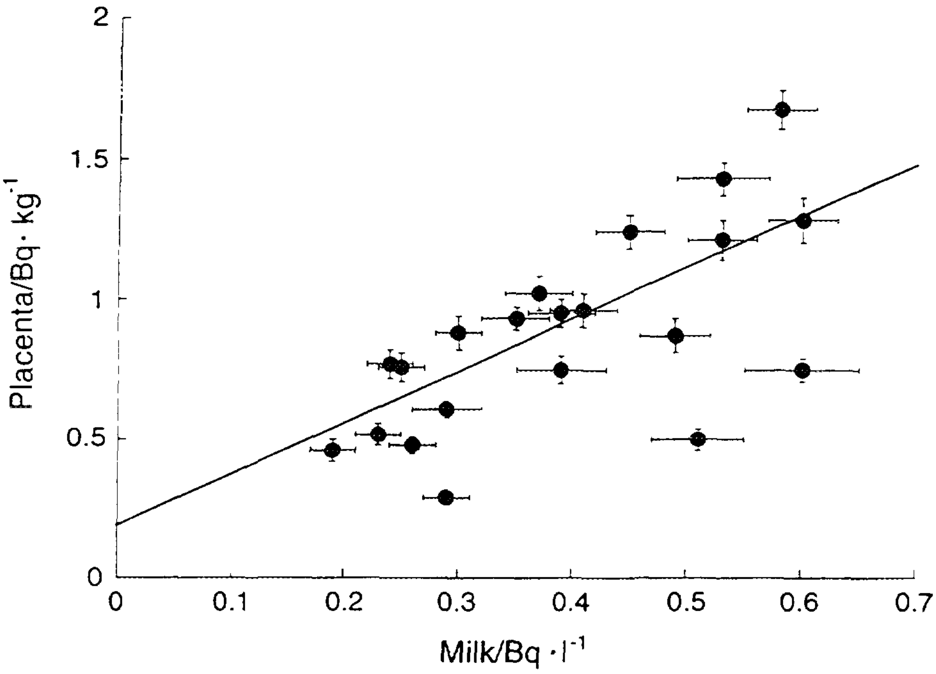

Figure 3. Cs-137 concentration in placenta versus Cs-137 concentration in maternal milk and linear regression.

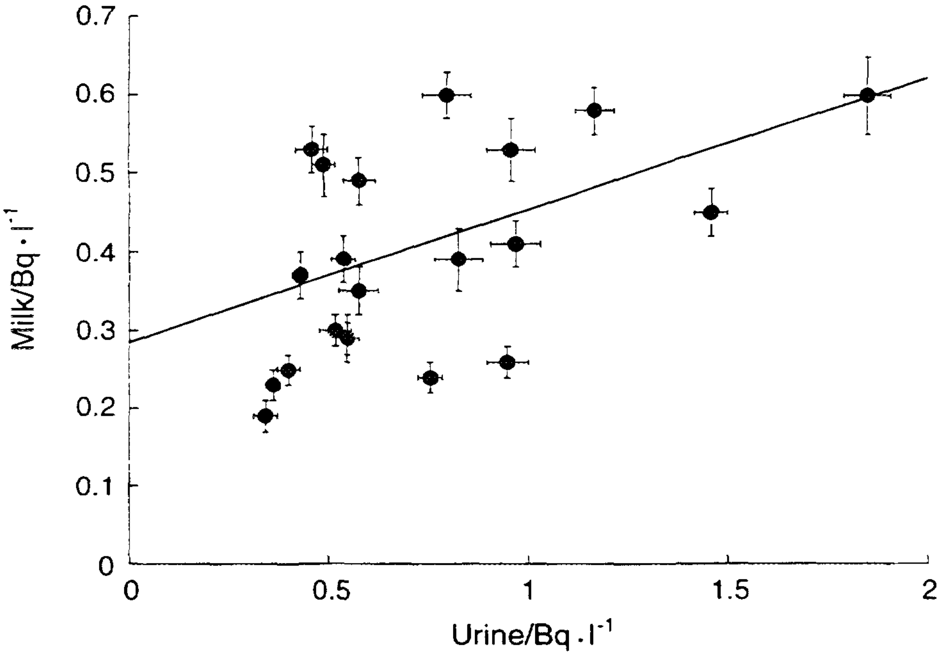

Figure 4. Cs-137 concentration in maternal milk versus Cs-137 concentration in urine and linear regression.

The transfer factor of Cs-137 from mother's diet to placenta (f_p) was calculated for each woman as the ratio of its concentration in mother's placenta to the daily intake. Its mean value is 0.5±0.2 d kg^{-1} with a range from 0.15 to 0.76 d kg^{-1}. Only a very few studies dealing with Cs-137 radioactivity in placenta have been carried out after the Chernobyl accident. In Italy one research regarding the Cs-137 levels in placenta was conducted from June 1986 to September 1987[6]; the value obtained for f_p was 0.48 d kg^{-1}.

Using mean daily intake values for the 21 women and the dose per unit intake coefficients[7], the mean committed effective dose to foetus for Cs-137 intake by mother's ingestion for the year including pregnancy was also evaluated. This dose is equal to ~10 μSv. It is also possible to evaluate[7] the mean body activity of the infant at birth time; the value obtained is equal to ~15 Bq.

4. CONCLUSIONS

In this paper the correlation between Cs-137 radioactive contamination of maternal milk, placenta and urine has been studied on a group of 21 women living in the Como Lake area.

As to urines, this study aimed at verifying the existence of a simple correlation between Cs-137 concentration in maternal milk and its concentration in urines, so that this last biological sample could be used for a quick assessment of caesium content in maternal milk. The obtained results do not seem to confirm this assumption completely. However, the work in progress, that is the evaluation of urine creatine and successive analyses of the data, hypothesizing different types of correlations, would improve the comprehension of the transfer from one compartment to the other.

The K-40 concentrations of maternal milk, placenta and urine have been measured and are discussed. A possible extension of this work would be the study of the ratio Cs/k in the mother's diet and their milk, placentae and urine.

Moreover, the Cs-137 transfer factor from diet to placenta was calculated; the obtained value is in good agreement with that evaluated by other authors.

Finally, the Cs-137 mean effective dose to foetus by mother's ingestion of contaminated food and the mean newborn body activity were assessed.

ACKNOWLEDGEMENTS

This work could not have been carried out without the support of F.Felici, which is sincerely acknowledged. Moreover, the authors express their gratitude to P.Di Ciaccio and M.Sabatini for their generous assistance.

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DELAYED MOBILISATION OF Sr-90 ASSOCIATED WITH FUEL PARTICLES

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Following accidental releases from nuclear installations, information on the source terms, and processes influencing radionuclide mobility and biological uptake within the affected ecosystem is needed for assessing long-term consequences. Information on source terms (composition, activity level, physico-chemical forms) is usually restricted to the list of inventory, or total activities of radionuclides released or deposited, while consideration with respect to radionuclide speciation are rarely taken into account.

Following the Chernobyl accident released radionuclides were present in different physico-chemical forms, i e volatiles, and associated with condensed and fuel particles. Close to the source, i e. within the 30 km zone, the deposition of fuel particles were high and the biological uptake in vegetation of fallout ^{137}Cs was low (Bondar et al, 1992). With increasing distance from Chernobyl, a decrease was observed, not only in the total activity level and in the relative contribution from ^{90}Sr, transuranics and refractory fission products, but also in the size and number of deposited fuel particles. However, small fuel particles were identified even in far distant areas i.e Scandinavia (Devell et al., 1986, Salbu, 1988).

Fuel particles collected from inside and outside the Chernobyl reactor, and contaminated soils from Ukraine, Belarus, Russia and Scandinavia have been subjected to a comprehensive analytical programme. Using electron microscope equipped with X-ray microanalyzer large differences in size, colour, composition and structure were observed The most striking feature was the presence of large aggregates consisting of small (μm) spheres Weathering could partly be associated with the desintegration of aggregates into separated spheres

Sequential extractions have been used to study the distribution of radionuclides in mobile (reversible processes) or inert (irreversible processes) forms in the soil-water system. In soils containing fuel particles the extractability of ^{137}Cs and ^{90}Sr was very low In general, the distribution especially of ^{90}Sr mobile and inert soil fractions was significantly different between that of stable Sr, i e stable Sr was predominantly present in mobile forms while ^{90}Sr in soils containing fuel particles was predominantly inert The relative fraction of ^{90}Sr (^{90}Sr/stable Sr) in mobile forms in soil water systems i e the mobility factor increases with distance from the source (Belarus > Russia > Norway) and increases with time after deposition

After deposition, time-dependent transformation processes influencing the radionuclide speciation occurs (Fig. 1). Due to weathering of fuel particles, radionuclides are released to the soil-water system. The radionuclides may then distribute between species in soil solution (ions, complexes, colloids) and species reversibly (physical or electrochemical sorption), and irreversibly (chemicsorption) fixed to solid soil components. For ^{90}Sr the rate of weathering and mobilization into soil solution are higher than the rate of fixation to solid soil components. Thus delayed mobilization of ^{90}Sr and a subsequent increase in the biological uptake is predicted for the fuel particle contaminated areas.

The paper will summarise several years of research on fuel particles at collaborating institutes, with special emphasis on the delayed mobilization of ^{90}Sr

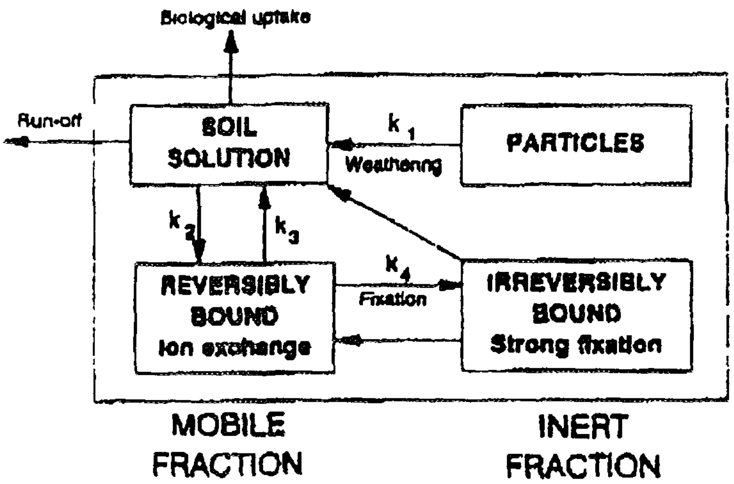

Figure 1. Distribution of radionuclides in contaminated soils

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PROGNOSES OF PLANT COMMUNITY CHANGES IN THE TERRITORIES NOT USED FOR AGRICULTURE AFTER THE ACCIDENT AT THE CHERNOBYL NUCLEAR POWER PLANT

XA9745837

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ПРОГНОЗ ИЗМЕНЕНИЯ РАСТИТЕЛЬНЫХ СООБЩЕСТВ НА ТЕРРИТОРИЯХ, ВЫВЕДЕННЫХ ИЗ СЕЛЬСКОХОЗЯЙСТВЕНННОГО ИСПОЛЬЗОВАНИЯ ПОСЛЕ АВАРИИ НА ЧЕРНОБЫЛЬСКОЙ АЭС

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Science-research works conducted in the zones of eviction in the Bragin district of the Gomel region testify to the fact that there is interdependence between development of plants'communities and such factors as type of soil, kind of agricultural field, the term of nonuse.

The study of vegetation change on the former fields, represented by turf-podsol soil, indicates that plant community has by now been formed on it, in which out of 100% projection cover prevail Artemisia absinthium L., - 40%, Artemisia campestris L.-20%, Artemisia vulgaris L. - 5%, Elytrigia repens (L.) Nevski - 30 % .

On lower lots, represented by turf-podsol swampy soil, the character of vegetation is different. Here prevail Elytrigia repens - 60%, Artemisia absinthium - 20%, Erigeron canadensis - 10% .

So, on the arable land not used one observes the tendency to forming communities of Elytrigia repens. One may suppose that in 10-15 years there may be a community here, consisting of bunch-grasses and densely turfed grasses.

On the haymaking and pasture meadows, situated on mineral soils, after their use also takes place rebuilding of plant cover. Sowing plants fall out, and take root rhizome bunch-grasses (Poa pratensis L.) rhizome (Elytrigia repens) and diverse grasses (Artemisia absinthium, Achillea millefolium, Erigeron canadensis and others).

On sowing meadows, situated on peat-swamp soil, after falling out of sowing plants, Urtica dioica L. took root. It formed powerful herbage with 80-90% projection cover, wich prevents the renewing of grasses.

Only after gradual decrease Urtica dioica there will appear from seeds stoks in the soil different grasses, as well as rhisome grasses. In future this land can be used for haymaking.

It is impossible to use this kind of soil without herbicides in large quantity, which may create additional problems of ecological character.

Выведение сельскохозяйственных угодий из оборота в результате аварии на ЧАЭС, привело к коренному изменению фитоценозов.

Существенное влияние на изменение растительных сообществ оказывают вид сельхозугодий, продолжительность периода отчуждения, тип почвы.

Приводится описание новых растительных сообществ, возникших на бывшей пашне, а также характер измения фитоценозов на окультуренных и естественных сенокосно-пастбищных угодьях зоны отселения.

Предложены пути и способы рекультивации бывших сельскохозяйственных угодий.

1. ВВЕДЕНИЕ

Авария на Чернобыльской АЭС признана самой крупной техногенной катастрофой планеты. Площадь загрязнения радионуклидами составила более 23% от общей территории республики. 264 тысячи гектар сельскохозяйственных угодий выведено из оборота

Выведенные из оборота земли представлены территориями зон отселения и отчуждения.

Зона отчуждения, или 30-км зона представляет собой компактную наиболее загрязненную радионуклидами территорию. Вывод земель из оборота производился единовременно, сразу после аварии на ЧАЭС.

Формирование территории зоны отселения, в отличии от формирования зоны отчуждения, происходило в несколько этапов.

В августе - сентябре 1986г. был проведен первый этап отселения жителей из хозяйств Брагинского, Хойникского, Наровлянского районов, прилегающих к 30-км зоне. Основанием для проведения отселения послужила мощность экспозиционной дозы.

Следующий этап формирования зоны отселения начался в 1990 году, после принятия закона Республики Беларусь "О социальной защите граждан, пострадавших от аварии на ЧАЭС", когда критерием отселения являлась плотность радиоактивного загрязнения сначала свыше 40 Ки/кв км, а затем свыше 15 Ки/кв км Cs-137 и плотности загрязнения Sr-90 свыше 3 Ки/кв км.

Различия во времени изьятия земель из сельхозоборота и использование неодинаковых критериев привело к тому, что территории зоны отчуждения и отселения значительно отличаются по плотности загрязнения радионуклидами и степенью проявления сукцессий.

Выведение сельскохозяйственных угодий из оборота привело к значительному снижению обьемов производства сельскохозяйственной продукции и изменению структуры посевных площадей.

В сложившейся ситуации имеет место несанкционированное использование земель, особенно сенокосно-пастбищных угодий, граничащих с населенными пунктами.

Процесс перевода земель, выведенных из оборота, в хозяйственное использование достаточно сложен и на первых этапах предполагает сбор информации по радиоэкологической ситуации и состоянию растительного покрова.

2. МЕТОДЫ ИССЛЕДОВАНИЙ

Научно-исследовательские работы, связанные с изучением радиоэкологической ситуации проводили в зоне отселения Брагинского района Гомельской области Республики Беларусь.

Растительный покров описывали по методике Миркина- Розенберга, с указанием общего проективного покрытия и проективного покрытия отдельных видов растений, в процентах.

Плотность загрязнения территории определяли путем отбора проб почвы специальным пробоотборником согласно методике " Обследование, оценка радиационной обстановки и построение карт загрязнения радионуклидами территории Республики Беларусь".

Определение содержания Cs-137 в почвенных и растительных пробах проводили на гамма-спектрометрах - ADCAM-300, NOKIA 4600 LP. Sr -90 определяли радиохимическим методом с радиометрическим окончанием на CANBERRA 2404.

3. РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ

Основная часть сельскохозяйственных угодий выведенных из оборота сосредоточена в зоне отселения и составляет около 200 тысяч га. В связи с этим, исследования проводили в зоне отселения Брагинского района на территории бывшего совхоза "Савичи".

Характерной особенностью этого хозяйства является то, что в результате аварии на ЧАЭС, часть территории оказалась в 30 км зоне, а часть - в зоне отселения. В 1986 году совхоз был расформирован. Следует отметить, что использование части пашни продолжалось до 1988 года.

Радиологическое обследование территории показало чрезвычайную пестроту радиоактивного загрязнения Cs-137.

Плотность загрязнения составляла от 144,6 до 8486,9 кБк/кв м (от 4,2 до 38,2 Ки/кв км).

Несанкционированное использование пашни, выведенной из оборота на протяжении 1986-1988гг привело к сравнительно равномерному распределению радионуклидов в обрабатываемом слое почвы . В зависимости от глубины отвальной обработки, радиоцезий сосредоточен в слое 0-15 или 0-20 см. В слое 20-25 см содержание Cs-137 заметно ниже.

На сельскохозяйственных угодьях, не обрабатываемых с 1986 года, основная часть радионуклидов, 60-86%, находится в слое 0-5 см. От 7 до 31 % выпавшего радиоцезия находится в горизонте 5-10см. В нижних горизонтах, то есть 10-15, 15-20, 20-25 см содержится около 0,9-5,9 % Cs-137.

Таким образом, за прошедшее после аварии время значительной вертикальной миграции радионуклидов, на исследуемых типах почв не произошло.

Отмечено изменение размеров поступления радионуклидов в естественную растительность в зависимости от распределения изотопов по профилю почвы.

Коэффициенты пропорциональности (отношение содержания радионуклида в единице растительной массы к содержанию радионуклида на единице площади - - Бк/кг:кБк/кв м) Cs- 137 в травостой на минеральных почвах, подвергшихся обработке составляет 0,23 - 1,42; на необрабатываемых - 0,83-2,84%.

Наиболее высокое содержание радиоцезия в растениях отмечается на торфяно-болотных почвах. Величина коэффициента пропорциональности составляет 10,12-51,75.

Определенное влияние на размеры накопления радиоцезия в растениях оказывают и их биологические особенности. Собранные в процессе обследования растительные пробы были разобраны на две группы - злаковые и разнотравье. Содержание Cs- 137 в злаках, произраставших на минеральных почвах, составляло 162 - 489 Бк/кг,а в разнотравье - 174 - 1176 Бк/кг. На торфяно-болотных почвах размеры перехода радиоцезия в растения были заметно выше. Так, в злаках Cs-137 содержалось 12398-206264 Бк/кг, в разнотравье - 16784-447538 Бк/кг.

Основными видами сельскохозяйственных угодий, на территориях, выведенных из оборота, являются пашня,естественные и окультуренные сенокосы и пастбища, многолетние насаждения.

Из этих сельхозугодий наибольшему антропогенному воздействию подвергались пашенные земли, в меньшей мере окультуренные сенокосно - пастбищные угодья, еще в меньшей - естественные сенокосы и пастбища.

Можно отметить, что чем более интенсивным было использование сельхозугодий, тем более сильные изменения происходят на них после вывода из оборота. Значительное влияние на формирование новых растительных сообществ оказывают почвенные особенности, или тип почвы.

В настоящее время на пашне, которая выведена из оборота на дерново-подзолистых слабооподзоленных почвах на водноледниковых связных песках, сменяющихся рыхлыми песками с глубины 25 см, дерново-подзолистых слабооподзоленных временно избыточно увлажненных почв на водноледниковых связных песках, сформировались растительные сообщества в которых по проективному покрытию преобладает полынь горькая -40%, полынь равнинная -20%, полынь обыкновенная - 5%, пырей ползучий - 30%. В небольших количествах также встречаются тысячелистник обыкновенный, льнянка лекарственная, мелколепестник канадский, редька дикая, звездчатка злаковидная, хвощ полевой.

На дерново-подзолистых слабооподзоленных временно избыточно увлажненных почвах на водно-ледниковых рыхлых песчанисто -пылеватых супесях, сменяющихся связными песками, а также на дерново-подзолистых глееватых почвах на водно-ледниковых связных песчанисто-пылеватых супесях, сформировались растительные сообщества в которых преобладают пырей ползучий - 60%, полынь горькая - 20%, мелколепестник канадский - 10%, клевер пашенный, ястребинка волосистая, вьюнок полевой, щетинник сизый, подорожник ланцетолистный с проективным покрытием менее одного процента каждый.

Следует отметить, что на пашне идет процесс вытеснение полыней пыреем ползучим.

Растения по жизненному состоянию (высота, количество побегов, ширина листовой пластинки и т.д.) невысокого жизненного уровня. В этих растительных сообществах затруднено семенное обновление и начинают преобладать виды с вегетативным возобновлением (пырей ползучий). Источником разнообразия видового состава явились некоторые участки сорной растительности (в связи с отсутствием мер борьбы с сорной растительностью), а также запасы семян сорняков в почве.

В целом на пашне, выведенной из оборота, наблюдается тенденция к образованию сообществ из пырея ползучего. Можно предположить, что в дальнейшем здесь будет злаковое сообщество, состоящее из корневищных рыхлокустовых и плотнокустовых типов растений.

Для введения их в оборот, необходимо применение гербицидов, с последующей разделкой пласта дернины тяжелыми дисками или фрезами. Можно также в первые годы освоения использовать эти земли для создания сенокосно-пастбищных угодий с последующей трансформацией их в пашню, применив систему полевых севооборотов.

На пашне, где в 1986г было проведено залужение многолетними травами: ежой сборной, овсяницей луговой, тимофеевкой луговой также происходит смена растительных сообществ.

Проективное покрытие злакового травостоя составило 45-55%. Идет выпадение сеяных трав и внедрение корневищно-рыхлокустовых (мятлик луговой), корневищных (пырей ползучий), а также разнотравья, полыни, тысячелистника, мелколепестника.

На отдельных участках, имеющих повышенный характер рельефа, от сеяных трав осталось 15-20%, на месте выпавших трав внедрились пырей ползучий, мятлик луговой, из разнотравья - мелколепестник канадский. Сеяные травы низкорослые.

Следует обратить внимание на тот факт, что все описываемые сельскохозяйственные угодья значительно повреждены дикими животными. Это затруднит поверхностное улучшение угодий. В связи с этим для проведения полноценного залужения многолетними травами необходим комплекс культуртехнических работ.

Основное количество окультуренных и естественных сенокосов и пастбищ находится на пойменно-аллювиальных, торфяно-болотных и дерново-подзолистых почвах. Основное отличие данного типа угодий от пашни - более низкая степень окультуренности и продуктивности.

Существенные изменения растительных сообществ отмечаются на окультуреннных сенокосно-пастбищных угодьях.

Неиспользуемые сенокосы и пастбища зоны к настоящему времени деградировали, в травостоях преобладают малоценные, но наиболее устойчивые к зацелиниванию виды многолетних злаковых трав, что привело к резкому снижению их продуктивности.

Сеяные травы выпадают, внедряются корневищно-рыхлокустовые (мятлик луговой), корневищные (пырей ползучий), и разнотравье (полынь горькая, тысячелистник обыкновенный, мелколепестник канадский).

На части торфяно-болотных почв, происходит закустаривание и заболачивание лугов.

На торфяно-болотной почве, место выпавших многолетних трав занимают крапива двудомная, дербенник иволистный, вербейник обыкновенный, причем крапива составляет 70-89% внедрившихся трав, также в составе травостоя встречаются горец почечуйный, марь белая, дрема белая, осот болотный, звездчатка злаковидная.

Травостой высокорослый, высотой более 1 метра, мощный.

Только после постепенного изреживания крапивы двудомной будет появляться разнотравье из запасов семян в почве, а также корневищные злаки. В будущем эти участки можно будет использовать как сенокосы.

Освоение данного типа почв невозможно без применения гербицидов в повышенных количествах, что может создавать дополнительные проблемы экологического характера.

На торфяно-болотных почвах, находящихся на растоянии нескольких километров от существующих населенных пунктов, происходит постоянное использование травостоя. В связи с этим, безусловно, деградация наблюдается, но не в такой степени, как на лугах не используемых.

Естественный травостой можно характеризовать как злаково-осоковоразнотравный с преобладанием мятлика болотного, щучки дернистой, осоки лисьей, лапчатки прямостоячей, лапчатки гусиной и др.

Окультуривание этих угодий может осуществляться по обычной технологии коренного улучшения сенокосов и пастбищ.

4. ЗАКЛЮЧЕНИЕ

Снятие антропогенной нагрузки на природную среду привело к коренному изменению состава и структуры фитоценозов.

Установлено наличие взаимосвязи между развитием растительных сообществ и такими факторами как вид сельхозугодий, продолжительность периода отчуждения, тип почвы.

В целом, на пашне выведенной из оборота, к десятому году после отчуждения , процесс демутации растительного покрова прошел стадии одно -двулетних и многолетних сегетальных видов и достиг корневищной стадии с преобладанием пырея ползучего. Можно предположить, что через 10- 15 лет процесс изменения растительного покрова приведет к увеличению обилия корневищно -рыхлокустовых и кустовых злаков и появлению кустарниковой растительности.

На окультуренных сенокосно-пастбищных угодьях, расположенных на минеральных почвах, после прекращения их использования, также происходит перестройка растительного покрова. Сеяные травы выпадают, внедряются корневищно-рыхлокустовые (мятлик луговой), корневищные (пырей ползучий), и разнотравье (полынь горькая, тысячелистник обыкновенный, мелколепестник канадский).

Луга, расположенные на торфяно-болотных почвах, в случае продолжения их использования деградируют значительно меньше по сравнению с неиспользуемыми, которые подвержены заболачиванию и замене травянистого типа растительности кустарниковым и древесным.

PROBLEMS OF PREDICTING THE RADIOECOLOGICAL AND RADIOBIOLOGICAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT IN BELARUS

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ПРОБЛЕМЫ ПРОГНОЗНОЙ ОЦЕНКИ РАДИОЭКОЛОГИЧЕСКИХ И РАДИОБИОЛОГИЧЕСКИХ ПОСЛЕДСТВИЙ ЧЕРНОБЫЛЬСКОЙ КАТАСТРОФЫ В БЕЛАРУСИ

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Принципиально важным обстоятельством является не только оценка непосредственных последствий Чернобыльской катастрофы, но и их прогноз. К настоящему времени в результате выполненных исследований получено достаточно большое количество информации о радиационной обстановке, миграции и формам нахождения радионуклидов в различных экосистемах, включению радионуклидов в трофические цепи и накоплению их в живых организмах. Оценены также биологические последствия действия сложившейся радиационной обстановки на важнейшие функциональные системы организма, метаболические процессы, функцию генома, заболеваемость населения и т. д. Указанные процессы изучены в динамике в послеаварийные годы. При этом полученные данные свидетельствуют о фазности изменений отдельных систем и различной их направленности: для одних - активация на начальном периоде, в последующем тенденция к восстановлению исходного уровня, однако переходящая затем к угнетению; для других систем - прогрессирующее расстройство, начиная с первоначальных сроков; для третьих - отсутствие достоверных изменений.

На основании полученных в 1986-1987 гг. данных и имеющихся сведений по другим ядерным авариям и глобальным выпадениям, а также рекомендаций международных организаций были подготовлены первые прогнозные оценки. Дальнейшие наблюдения в динамике за происходящими процессами потребовали внесения в эти оценки во многих случаях существенных корректив. Так, оказалась различной динамика миграции и форм нахождения радионуклидов. Например, усьановлены различные с годами скорости миграционных процессов для цезия-137 и стронция-90, изотопов плутония и америция-241, а также различная степень перехода их из фиксированного состояния в подвижные формы. Показано существенное влияние на эти процессы особенностей химического, гранулометрического состава почв, их увлажненности, ландшафтно-геохимический условия и других факторов. Выявлена сложность коррелятивных взаимоотношений между полученной дозой облучения и биологическим эффектом, что обусловило в ряде случаев непрогнозированное в такие сроки и в таком масштабе появление патологии, например, рака щитовидной железы. Это потребовало учета ряда дополнительные факторов, в частности, реконструкции дозовых нагрузок на начальном этапе аварии, с учетом короткоживущих радионуклидов, ингаляционного поступления радионуклидов, одновременного действия на организм различных радионуклидов и других повреждающих факторов, когда биологический эффект может не только суммироваться, но и потенцироваться, "горячих частиц" и т. д. Все это обусловило необходимость пересмотра начальных прогнозных оценок, в равной степени, как и анализа самих полученных данных. Сейчас очевидно, что в силу особенностей для отдельных регионов динамики и характера радиоактивного загрязнения, необходимости учета многофакторности самой аварии и локальных условий, более достоверными и объективными оказались региональные прогнозы, что в настоящее время и проводится. Указанные и другие проблемы на конкретном материале будут обсуждены в докладе.

FUNDAMENTAL PRINCIPLES FOR OBTAINING AGRICULTURAL PRODUCE OF STANDARD PURITY IN THOSE PARTS OF THE RUSSIAN FEDERATION WHICH WERE RADIOACTIVELY CONTAMINATED AS A RESULT OF THE CHERNOBYL ACCIDENT, AND THE EFFECTIVENESS OF THE MEASURES BEING TAKEN

XA9745839

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ОСНОВНЫЕ ПРИНЦИПЫ ПОЛУЧЕНИЯ НОРМАТИВНО ЧИСТОЙ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ПРОДУКЦИИ НА ТЕРРИТОРИИ РФ, ПОДВЕРГШЕЙСЯ РАДИОАКТИВНОМУ ЗАГРЯЗНЕНИЮ В РЕЗУЛЬТАТЕ АВАРИИ НА ЧАЭС И ЭФФЕКТИВНОСТЬ ПРОВОДИМЫХ МЕРОПРИЯТИЙ

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При радиационных авариях, которые сопровождаются выбросами радиоактивных веществ в окружающую среду и загрязнением сельскохозяйственных угодий, поступление радионуклидов в агропромышленную продукцию приводит к формированию дополнительного источника облучения человека. В противоположность внешнему облучению, ограничение воздействия которого экономически достаточно дорогостояще, регулирование внутреннего облучения, т.е. изменение поступления радионуклидов в организм человека с местными продуктами питания, рассматривается как реально достижимый способ снижения суммарных дозовых нагрузок на население. Для этого необходима разработка систем земледелия, с одной стороны, обеспечивающих повышение продуктивности агроценозов, сохранение плодородия почв, снижение уровня загрязнения получаемой продукции радиоактивными веществами, а с другой, гарантирующих экологически безопасное функционирование сельскохозяйственного производства. Для решения этих вопросов необходимо проведение комплекса контрмер в растениеводстве и животноводстве.

Результаты проведенных нами исследований свидетельствуют о том, что гарантированное получение доброкачественной продукции растениеводства достигается оптимизацией технологий возделывания сельскохозяйственных культур при качественном выполнении всех агротехнических операций и внедрением приемов, способствующих снижению перехода радионуклидов в растения. Применение агромелиорантов (вермикулит, бентонит), способных к необменной сорбции радионуклидов в почвах, снижает накопление ^{137}Cs в урожае от 1,5 до 3 раз. Этот прием необходимо внедрять при улучшении травостоев кормовых угодий на торфяных почвах, где из-за низкого содержания глинистых минералов, накопление радионуклидов в урожае трав в 3 - 4 раза выше, чем на дерново-подзолистых.

При перезалужении сенокосов и пастбищ на сеянных травах и коренном улучшении естественных кормовых угодий обработка почвы и тщательное разрушение дернины позволяет снизить концентрацию радионуклидов в лугопастбищной растительности от 1,5 до 10 раз.

Использование минеральных, органических удобрений и известковых материалов, традиционных в растениеводстве приемов получения стабильно высоких урожаев. позволяет регулировать содержание радионуклидов в продуктах питания, особенно на малоплодородных неокультуренных почвах.

Внесение высоких доз азотных удобрений, особенно при несбалансированном соотношении азота, фосфора и калия в почвах снижает качество получаемой сельскохозяйственной продукции, а переход ^{137}Cs в растения заметно повышается (в 1,5-2 раза).

Снижение концентрации радионуклидов в продукции растениеводства (до 3 раз) достигается при совместном внесении калийных удобрений и известковых материалов, особенно на почвах с низкой обеспеченностью обменным калием и кальцием.

При возделывании сельскохозяйственных культур в севооборотах технология обработки почвы позволяет уменьшить концентрацию радионуклидов в продукции растениеводства. Глубокое безотвальное рыхление дерново-подзолистой песчаной почвы приводит к перераспределению за пределы пахотного горизонта до 20% ^{137}Cs, что снижает переход радионуклида в урожай до 2 раз.

Одним из наиболее результативных приемов, экономически недорогостоящим, на пахотных и кормовых угодьях в условиях радиоактивного загрязнения является подбор наиболее продуктивных видов и сортов культур, характеризующихся минимальным накоплением радионуклидов. Видовые различия в аккумуляции ^{137}Cs могут достигать от 2 до 45 раз. Сортовые различия значительно меньше и составляют от 2 до 5 раз.

Основой получения продукции животноводства, полностью пригодной в пищу человека, служит рациональная организация кормопроизводства, обеспечение животных полноценными, сбалансированными рационами с минимальным содержанием радионуклидов, наличие в хозяйстве высокопродуктивных животных.

Достаточно высокий эффект наблюдался при переводе животных в летнее время с пастбищного на стойлово-выгульное содержание, включение в их рацион трав и сельскохозяйственных культур с минимальным накоплением радионуклидов. Это позволило исключить поступление в организм животных почвенных частиц (что особенно важно в случае использования низкопродуктивных пастбищ) и до 2-5 раз (а в некоторых случаях до 10 раз) снизить загрязнение продукции. Коренное улучшение лугов и пастбищ позволяет существенно снизить поступление ^{137}Cs в организм сельскохозяйственных животных с рационом, и как следствие, загрязнение молока и мяса в среднем до 3-5 раз. В качестве одного из основных приемов, обеспечивающих снижение содержания ^{137}Cs в мясе (до 2- 4 раз) широко использовалось содержание животных перед забоем на "чистых" кормах. В последние годы в практике ведения животноводства активно (хотя и в ограниченном объеме) используются кормовые добавки, включающие аммониево-железо-гексоцианоферраты, применение которых до 2 раз снижает переход ^{137}Cs в молоко коров.

Оценка эффективности комплекса мероприятий в реальных условиях, чему посвящена настоящая работа, представляет наибольший интерес с точки зрения определения общей эффективности мер по ликвидации последствий аварии наЧернобыльской АЭС.

ACCIDENT AT THE CHERNOBYL NUCLEAR POWER PLANT AND AGRICULTURAL PRODUCTION: ACHIEVEMENTS AND UNSOLVED PROBLEMS

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АВАРИЯ НА ЧЕРНОБЫЛЬСКОЙ АЭС И СЕЛЬСКОХОЗЯЙСТВЕННОЕ ПРОИЗВОДСТВО: ДОСТИЖЕНИЯ И НЕРЕШЕННЫЕ ЗАДАЧИ

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The accident at the Chernobyl NPP is the most serious one in the history of nuclear power resulting in the large-scale contamination of the environment in a heavily populated area where agricultural lands are actively used. Heavy radioactive contamination of vast areas generated a need to take comprehensive protective measures in the affected regions. Accidental radioactive contamination of the agricultural sphere is one of the sources of additional irradiation of population (due to the contaminated food consumption). Therefore, the implementation of countermeasures for mitigating accidental consequences in the agroindustrial complex occupies the leading place in the general volume of measures on radiation safety.

The major results achieved by large-scale implementation of countermeasures in agriculture on the territory of Russia affected by the Chernobyl NPP accident and their effectiveness are described. Among the problems that need to be solved in agriculture in the nearest future the following are identified: improvement of a network of agroecological monitoring in areas subjected to radioactive contamination for the development of reliable methods for predicting contamination of agricultural products; development of promising technologies for cultivating agricultural crops; assessment of effectiveness of all the countermeasures on the basis of the "risk-benefit" concept using radiological and economic criteria; development of a system of repeat agromeliorative measures, especially in meadow feed production; development of methods for radical improvement of floodplain and lowland meadows; development of new effective methods to reduce contamination of agricultural produce at each stage of its production and processing; the ensuring of the production of "clean" milk over the entire contaminated area; providing of safe private farming.

Авария на Чернобыльской АЭС в 1986 г. явилась крупнейшей в истории ядерной энергетики, что привело к массированному загрязнению окружающей среды, в том числе сельскохозяйственных угодий на значительных территориях. Общая площадь с плотностью загрязнения ^{137}Cs свыше 1 Ки/ км^2 охватила 3.2% европейской территории бывшего СССР. Интенсивное радиоактивное загрязнение обширных площадей привело к необходимости проведения широкого комплекса защитных и мелиоративных мероприятий в сельском хозяйстве региона, подвергшегося радиационному воздействию.

Радиоактивное загрязнение сферы сельскохозяйственного производства при авариях является одним из важнейших источников дополнительного облучения населения, вследствие чего выполнение мер по ликвидации последствий аварий в агропромышленном комплексе занимает ведущее место в общей системе мероприятий по обеспечению радиационной безопасности. В этих условиях производство “чистой” (отвечающей по содержанию радионуклидов допустимым уровням, установленным органами здравоохранения) сельскохозяйственной продукции на загрязненных угодьях является одним из важнейших показателей эффективности ликвидации последствий аварии. Во-первых, получение "чистой" продукции растениеводства и животноводства обеспечивает понижение суммарной дозы облучения вследствие уменьшения дозы внутреннего облучения. Во-вторых, как убедительно показывает 10-летний опыт ликвидации последствий аварии на ЧАЭС, производство "чистой" сельскохозяйственной продукции является одним из важнейших факторов психологической устойчивости населения. И, наконец, в-третьих, получение пригодной для потребления продукции (по содержанию радионуклидов) в личном секторе АПК служит одним из гарантов стабильности демографической инфраструктуры села в зоне аварии [1-3].

Следует подчеркнуть, что уже по истечении нескольких месяцев после аварии - после распада коротко- и значительной части среднеживущих радионуклидов и проведения экстренных дезактивационных работ мероприятия по уменьшению содержания радионуклидов в сельскохозяйственных продуктах становятся ведущим фактором уменьшения дозы облучения, так как возможность понижения дозы внешнего облучения на практике ограничена высокими экономическими затратами.

С точки зрения организации агропромышленного производства можно выделить несколько периодов при ликвидации последствий аварии с выбросом радиоактивных веществ в окружающую среду.

Первый (ранний) период занимает первые 10-12 дней после аварии. В этот период основные мероприятия в АПК сводятся к оперативной оценке радиологической ситуации, организации радиационного контроля, экспрессному бракеражу сельскохозяйственных продуктов, готовых к употреблению, а также бракеражу кормов, если содержание радионуклидов в пищевых продуктах и кормах превышает допустимые уровни; при необходимости проводится эвакуация сельскохозяйственных животных.

Присутствие после аварии на ЧАЭС в смеси выпавших радиоактивных веществ короткоживущих радионуклидов йода, с одной стороны, и нахождение животных на выпасе - с другой, предопределили возникновение йодной опасности, связанной с быстрым переходом радиойода в молоко. В первые два месяца после аварии были выполнены большие работы по ограничению потребления свежего молока и его переработке на масло.

Второй период занимает до 2-3 мес. после аварии. В этот период выполняется радиологическое картирование загрязненных угодий, совершенствуется система радиационного контроля сельскохозяйственных угодий и производимой агропромышленной продукции, начинаются агромелиоративные мероприятия, реализуется программа по технологической переработке сельскохозяйственных продуктов.

Третий период заканчивается по истечении первых полутора лет после аварии. В эти сроки выполняются на научной основе агромелиоративные мероприятия, завершается основной объем мероприятий по детальному радиологическому контролю загрязненных угодий. Формируется научно обоснованная программа ведения АПК на загрязненной территории, направленная на максимальное получение "чистой" продукции и рациональное использование сельскохозяйственных угодий.

Четвертый период начинается по истечении 1.5-2 лет после аварии. При наличии в выпавшей смеси радиоактивных веществ долгоживущих радионуклидов (^{90}Sr, ^{137}Cs, ^{239}Pu и др.) в этот период на постоянной долголетней основе реализуется программа получения "чистой" продукции при выполнении длительно действующей системы агропромышленных мероприятий, перепрофилирования АПК и технологической переработки загрязненной продукции.

Основная информация о поведении ^{137}Cs в сельскохозяйственных цепочках до аварии на ЧАЭС была связана с изучением глобального ^{137}Cs после ядерных испытаний и растворимого ^{137}Cs (используемого в сельскохозяйственных радиоэкологических экспериментах). Анализ ситуации в зоне аварии ЧАЭС показал, что закономерности поведения "аварийного" ^{137}Cs и ^{137}Cs глобального происхождения достаточно близки и их перенос по сельскохозяйственным цепочкам описывается сходными количественными параметрами. Однако в ближней зоне (радиусом 30 км) большую роль могут играть формы ^{137}Cs, включенного в матрицу твэлов и конструкционных материалов. Биологическая подвижность этих соединений ^{137}Cs может существенно отличаться от мобильности глобального ^{137}Cs или аварийного ^{137}Cs в дальней зоне аварии [4].

Итоги детальной оценки интенсивности перехода основных радиологически значимых нуклидов по ведущим сельскохозяйственным цепочкам в системе почва - растения - животные - рацион человека позволили вы полнить зонирование всех сельскохозяйственных угодий по плотности загрязнения основным дозообразующим радионуклидом ^{137}Cs. С учетом временных предельно допустимых уровней содержания ^{137}Cs в сельскохозяйственной продукции было признано целесообразным организацию ведения агропромышленного производства дифференцировать по следующим трем зонам - соответственно до 5, 15-40 и свыше 40 Ku/ км^2 (по ^{137}Cs). Интенсивность проведения защитных мероприятий в сельском хозяйстве и комплекс самих мероприятий были разными в указанных зонах [3, 5-7]. Для уменьшения перехода радионуклидов в сельскохозяйственные растения и накопления их в урожае на пахотных угодьях был рекомендован комплекс агротехнических и агрохимических мероприятий. Агротехнические приемы включали проведение заглубленной вспашки, увеличение доли площадей под культуры с низким уровнем накопления радионуклидов и предотвращение вторичного загрязнения растений путем сокращения количества междурядных обработок. Агрохимические мероприятия предусматривали известкование кислых почв(дозы извести из расчета 1,5-2,0 Нг), внесение повышенных доз фосфорных и калийных удобрений (2Р-2К), добавление органических удобрений (более 40 т/га) и природных минералов сорбентов [5-7].

В луговом кормопроизводстве к числу ведущих агромелиоративных приемов, обеспечивающих максимально возможное уменьшение перехода ^{137}Cs в растения, относится мелиорация сенокосов и пастбищ.

Сводные данные об эффективности защитных мероприятий в сельском хозяйстве на территории, подверженной воздействию аварии на Чернобыльской АЭС, приведены в табл. I

Таблица I

Эффективность различных защитных мероприятий в сельском хозяйстве в регионе аварии на Чернобыльской АЭС (по снижению содержания ^{137}Cs в продукции)

Защитные мероприятия	Эффективность
Мелиорация лугов и пастбищ	2,5-8
Применение минеральных удобрений	1,5-2,5
Известкование кислых почв	1,5-2,0
Технологическая переработка молока на масло	10 - 15
Применение ферроцианидов при получении молока	4 - 5
Подбор растений с минимальным накоплением ^{137}Cs	
а) видовое разнообразие	до 10
б) сортовое разнообразие	до 4,5

Радиологический контроль продукции, производимой в наиболее загрязненных регионах России (западные районы Брянской и Калужской областей), показал, что с 1987 г. концентрация ^{137}Cs в агропромышленной продукции заметно снизилась. При этом можно выделить два, а в некоторых случаях три периода, характеризующиеся разными темпами снижения загрязнения. Наиболее быстрым оно было в первый период после аварии. Начиная с 1990 г. темпы уменьшения загрязнения сельскохозяйственной продукции замедлились. С 1987 по 1992 гг. концентрация ^{137}Cs в продукции снизилась от 5 до 30 раз, причем наиболее существенно в зерне - от 15 до 30 раз. Менее резко выражено уменьшение содержания ^{137}Cs в клубне- и корнеплодах, а также в сене и силосе. Снижение биологической доступности ^{137}Cs за счет протекания естественных биогеохимических процессов обусловлено 46% уменьшение содержания ^{137}Cs в растениеводческой продукции, вклад радиоактивного распада составлял 5%, а на долю защитных мероприятий приходилось 49%. [8].

В связи с различной динамикой содержания ^{137}Cs в отдельных видах сельскохозяйственной продукции для оценки его снижения были рассмотрены следующие показатели:

- средний период полуснижения загрязнения - с 1987 по 1992 гг.,
- первый период полуснижения загрязнения: с 1987 по 1992 гг., когда закрепление радионуклидов в почве протекало наиболее интенсивно, а на сельскохозяйственных угодьях в широком масштабе было начато проведение защитных мероприятий;
- второй период полуснижения загрязнения: с 1989 по 1992 гг., когда темпы уменьшения накопления ^{137}Cs в сельскохозяйственной продукции замедлились, защитные мероприятия были уже проведены на большей части угодий и дальнейшее их применение не приводило к существенному снижению загрязнения продукции, а обеспечивало сохранение достигнутого в ней содержания ^{137}Cs.

Средний за весь промежуток времени - с 1987 по 1992 гг. - после аварии на ЧАЭС период полуснижения содержания ^{137}Cs в продукции растениеводства для Брянской области составил от 1,6 до 2,8 года, а для Калужской области от 2,3 до 6,9 года, что связано с различиями в объемах защитных мероприятий (Табл. II). Первый период полуснижения загрязнения в районах Брянской и Калужской областей довольно близок - от 1,0 до 2,3 года. Если внедрение защитных мероприятий было начато раньше и было проведено в больших объемах, уменьшение загрязнения продукции происходило более быстрыми темпами. В связи с этим второй период полуснижения загрязнения продукции в Брянской области был почти в 2 раза короче, чем в Калужской области [9].

Таблица II

Периоды полуснижения содержания ^{137}Cs в продукции растениеводства, годы [9]

Вид продукции	Период полуснижения загрязнения		
	средний	первый	второй
Брянская область			
Зерно	1,4-1,9	1,2-2,1	1,7-4,3
Картофель корнеплоды	1,5-2,8	1,4-1,9	2,2-7,7
Сено	1,5-1,9	0,9-1,4	1,7-7,3
Калужская область			
Зерно	3,1-4,9	-	
Картофель корнеплоды	3,2-5,6	2,9	5,8-14,1
Сено	2,0-3,0	1,4-2,3	3,3-4,8
Силос	2,3-2,9	1,0-1,8	3,0-13,8
Сенаж	2,8-6,9	1,6-2,2	6,9-13,8

В Российской Федерации основные радиологические исследования были сосредоточены в наиболее загрязненных районах - в Брянской, Калужской, Тульской и Орловской областях. Размеры загрязненных сельскохозяйственных угодий составляют около 5 млн. га, и еще большую площадь занимают загрязненные лесные массивы. В этих областях были созданы 4 полигона, на которых представлены наиболее характерные типы загрязненных почв: дерново-подзолистых, серых лесных и черноземов. Головным учреждением бывшего СССР, а затем России, ответственным за руководство соответствующими научными исследованиями и их координацию в регионе аварии, а также научное обеспечение внедрения рекомендаций по ведению сельского хозяйства на загрязненных территориях, был Всесоюзный (затем, с 1991 г., Всероссийский) научно-исследовательский институт сельскохозяйственной радиологии и агроэкологии (ВНИИСХРАЭ) с двумя его филиалами - Украинским (в Киеве) и Белорусским (в Гомеле), в последующем превратившимися в национальные центры по сельскохозяйственной радиологии Украины и Беларуси.

Защитные мероприятия в сфере сельскохозяйственного производства на радиоактивно загрязненной территории предложены для всех отраслей на определенных этапах после аварии на ЧАЭС. В земледелии разработаны эффективные методы химизации и апробированы способы обработки почвы, ведущие к ограничению перехода радионуклидов из почвы в растения. В реальных условиях по данным 10-летних исследований на территории России химизация земледелия обеспечивала снижение ^{137}Cs в растениях в среднем в 2-2,5 раза [5,7].

Во ВНИИСХРАЭ и учреждениях Минсельхозпрода Российской Федерации разработаны технические средства основной обработки почвы, загрязненных почв и возделывания сельскохозяйственных культур изготовлены макетные образцы машин и проведены их лабораторно-полевые испытания. На основании этих исследований рекомендовано в проект номенклатуры технических средств 12 марок тракторов и других самоходных машин и 26 наименований специальных видов разрабатываемых и модернизированных сельскохозяйственных машин, наиболее полно отвечающих требованиям работы на радиоактивно загрязненных сельхозяйственных угодьях.

В области растениеводства были отработаны технологии возделывания зерновых (озимая рожь, ячмень, овес), бобовых (люпин) и пропашных культур (картофель) для почвенно-климатических условий Брянской, Калужской, Тульской и Орловской областей.

В настоящее время оцениваются система повторных применений повышенных доз минеральных удобрений и предельные возможности агрохимических контрмер по уменьшению перехода радионуклидов в растения. В то же время наблюдения последних лет показывают, что при резком падении доз внесения минеральных удобрений в загрязненные почвы Брянской области (отсутствие удобрений, снижение финансирования проведения защитных мероприятий) отмечается повышение перехода ^{137}Cs в растения.

Достаточно эффективным защитным мероприятием являются подбор и использование сортов сельскохозяйственных культур с минимальной способностью к накоплению радионуклидов; как показали исследования ВНИИСХРАЭ и Московского отделения ВНИИ растениеводства, сортовые различия в коэффициентах накопления ^{137}Cs растениями могут достигать 7-10 раз. Завершается отбор районированных сортов (из 150 сортов зерновых, бобовых и картофеля), отличающихся минимальной способностью к накоплению радионуклидов [10].

Очень важное значение в снижении доз внутреннего облучения после аварии имело решение “молочной проблемы” - исключение из потребления молока, содержание радионуклидов в котором превышало ВДУ (сначала критическим радионуклидом был ^{131}I, а затем ^{137}Cs). В загрязненном регионе после аварии на ЧАЭС молоко было ответственно за 70% дозы внутреннего облучения [11].

В первый период после аварии (несколько месяцев) важное место занимали запретительные меры по использованию загрязненного выше допустимых уровней по ^{131}I молока (значительное количество такого молока было переработано на сгущеное или сухое, что при хранении обеспечивало распад короткоживущего ^{131}I). В последующий период (2-3 года) существенную роль сыграла переработка загрязненного молока на масло (отчасти сыр), что обеспечивало уменьшение концентрации ^{137}Cs в конечном продукте в 10-15 раз. Однако стратегически длительным направлением в производстве “чистого” молока явилась организация кормления лактирующих животных таким рационом, что исключало вообще получение молока с содержанием ^{137}Cs выше ВДУ. Это потребовало организации широкомасштабных исследований по оценке динамики перехода ^{137}Cs по “молочной” цепочке, с одной стороны, и детальных работ по радиационному мониторингу лугово-пастбищных угодий, - с другой стороны.

Опыт решения “молочной” проблемы выявил достаточно ограниченные возможности технологической очистки молока от радионуклидов (например, при использовании различных ионообменных смол, импрегнированных ферроцианидсодержащими соединениями фильтров и т.п.). Это касается как общественного, так и личного секторов сельского хозяйства, хотя и научные, и изыскательские работы показали достаточно высокую степень очистки молока при использовании указанных методов. Причинами такого ограниченного применения технологической очистки явились психологические мотивы у населения (насколько соответствует очищенный продукт натуральному молоку), экономические соображения и конкурентная способность метода деконтаминации относительно других способов производства молока, отвечающего радиологическим стандартам.

В первые два года после аварии возникли значительные трудности в производстве мяса, содержание ^{137}Cs в котором соответствовало бы временным допустимым уровням. Это явилось следствием сравнительно высокого содержания ^{137}Cs в луговой и пастбищной растительности. ^{137}Cs и другие радионуклиды задержались на довольно длительное время в так называемой луговой дернине, оставаясь на немелиорированных лугах и пастбищах из-за низкой фиксации радионуклидов повышено доступными для усвоения растениями. Особенно остро эти вопросы стояли в весенние и осенние периоды, когда животные выпасались на пастбищах с малым запасом фитомассы. Важно подчеркнуть, что в эти сроки при пастбищном содержании животных достаточно большое количество радионуклидов могло поступать в желудочно-кишечный тракт животных с почвой, заглатываемой при пастьбе.

Решение этой проблемы было достигнуто за счет перевода сельскохозяйственных животных в предубойный период на кормление относительно "чистыми" кормами. Внедрение метода предубойного перевода животных на относительно "чистые" корма потребовало разработки специальной аппаратуры для прижизненного измерения концентрации ^{137}Cs в сельскохозяйственных животных на уровне ВДУ в полевых условиях (на фермах). После конструкторских пилотных разработок была выпущена серия приборов, позволяющих с достаточной точностью измерять содержание ^{137}Cs в теле животных.

Для сортировки сельскохозяйственных животных перед убоем была разработана методика прижизненного определения содержания ^{137}Cs в мышцах. В настоящее время эта методика значительно усовершенствована с использованием современных приборов типа "Вольера-Б" и РСХП-ГН-01, которые отличаются высокой чувствительностью, обеспечивающей требования ВДУ-93 на мясо по концентрации ^{137}Cs (600 Бк/кг).

В особых случаях (для животных из личных подсобных хозяйств, при выпасе животных на заливных пойменных лугах и др.), когда невозможно обеспечение незагрязненными кормами, в практику рекомендуется внедрение системы содержания и откорма животных с применением специальных кормовых добавок и сорбентов, снижающих поступление ^{137}Cs в организм животных и продукцию животноводства и обеспечивающих гарантированное производство нормативно чистой продукции на радиоактивно загрязненных территориях. К настоящему времени в России разработаны 4 лекарственные формы ферроцианид содержащих препаратов, которые прошли производственные испытания в хозяйствах Брянской области [12]. Вместе с тем нужно подчеркнуть, что использование данных препаратов - это мера экстренная, вынужденная, а основным мероприятием должно быть коренное улучшение лугов и пастбищ, позволяющее получить корма, обеспечивающие производство "чистого" молока и мяса.

Наиболее трудной в радиологическом аспекте при ликвидации последствий аварии на ЧАЭС является проблема реабилитации отчужденных земель (исключенных из хозяйственного оборота сельскохозяйственных угодий из-за очень высоких уровней радиоактивного загрязнения). С течением времени по мере распада искусственных радионуклидов (естественного самоочищения природной среды), а также уменьшения интенсивности миграции долгоживущих радионуклидов по трофическим цепочкам (в первую очередь в системе почва - растение) создаются предпосылки для возвращения ранее отчужденных земель в хозяйственное пользование. Необходимость такого возвратного вовлечения угодий в оборот диктуется также комплексом социально-демографических и экономических факторов (несанкционированное использование этих угодий населением, исключение разноса радиоактивных веществ на прилегающие территории, психологически положительное влияние на население эффективного выполнения усиленного комплекса защитных мероприятий на этих площадях и т.п.).

К 1989 г. в агропромышленном комплексе на всей территории, подвергшейся радиоактивному загрязнению после аварии на Чернобыльской АЭС (за исключением районов отчуждения и отселения, где ведение сельскохозяйственного производства было прекращено), была решена одна из основных задач - практически прекратилось производство продукции, не отвечающей радиологическим нормативам, т.е. с превышением временных допустимых уровней содержания ^{137}Cs. Появилась возможность перехода к новому этапу ведения агропромышленного производства на загрязненных территориях, основная часть этого этапа-организация АПК таким образом, чтобы минимизировать коллективные дозы облучения населения вследствие потребления продукции с площадей, подвергшихся воздействию аварии.

В настоящее время практически вся сельскохозяйственная продукция, получаемая в загрязненных районах Российской Федерации, отвечает санитарно-гигиеническим требованиям, и стоит вопрос о повышении биологической полноценности продуктов для населения, проживающего в этих районах, путем внесения различных добавок (витамины, микроэлементы и др.). Особое внимание уделяется зонам отчуждения земель с плотностью загрязнения ^{137}Cs более 15 Ки/км^2. Выполняются работы по созданию экспертных систем поддержки принятия решений о проведении разработанных мероприятий на территориях конкретных загрязненных районов по критериям снижения индивидуальных и коллективных доз и экономической эффективности контрмер. Выполненный ВНИИСХРАЭ и более чем 30 институтами-соисполнителями большой объем комплексных исследований в натурных условиях на радиоактивно загрязненных территориях Российской Федерации позволил получить результаты, которые легли в основу разработанных и уточняемых систем ведения отраслей агропромышленного производства, обеспечивающих получение сельскохозяйственной продукции, полностью отвечающей радиологическим нормам.

При формулировании задач в агропромышленном производстве по ликвидации последствий аварии на ЧАЭС на ближайшие годы необходимо учитывать нерешенные до конца вопросы: улучшение лугов и пастбищ, особенно пойменных и заливных; обеспечение производства “чистого” молока на всей загрязненной территории; радиологически безопасное ведение личных подсобных хозяйств, обеспечение безопасной работы обслуживающего персонала на всех стадиях производства и переработки сельскохозяйственной продукции и др.

К таким основным задачам следует отнести:

- создание сети агроэкологического мониторинга на территориях, подвергшихся радиоактивному загрязнению, в целях анализа процессов миграции ^{137}Cs и темпов очищения сельскохозяйственной продукции в зависимости от почвенно-климатических условий и комплекса специальных агротехнологий. Выбор наиболее эффективных защитных мер для конкретных загрязненных районов и хозяйств, пострадавших в результате аварии на ЧАЭС;
- углубленное изучение биогеохимического круговорота радионуклидов в сфере агропромышленного комплекса в пространственно-временной структуре с оценкой транспорта радионуклидов в различных сельскохозяйственных звеньях;
- оценку эффективности всех выполняемых в агропромышленном производстве защитных мероприятий на основе концепции “риск-выгода” как по радиологическим, так и по экономическим критериям; разработку системы повторных агромелиоративных мероприятий, в первую очередь для естественных лугопастбищных угодий на дерново-подзолистых песчаных и супесчаных почвах, своими свойствами определяющих возможность обратной миграции ^{137}Cs в верхний почвенно-растительный слой;
- разработку новых эффективных методов снижения загрязнения сельскохозяйственной продукции на каждом из этапов ее производства и переработки;
- разработку способов коренного улучшения пойменных и заливных лугов;
- разработку рекомендаций по ведению агропромышленного производства на территории России, подвергшейся радиоактивному загрязнению в результате аварии на ЧАЭС, на период 1996-2000 гг. и более отдаленные сроки.

Заключение

При ликвидации последствий радиационных аварий с выбросом радиоактивных веществ в окружающую среду внедрение комплекса защитных мероприятий в агропромышленное производство представляет одно из ведущих звеньев в системе мер, обеспечивающих радиационную безопасность населения. При аварии на Чернобыльской АЭС в 1986 г. с потреблением сельскохозяйственной продукции, содержащей радионуклиды, было связано не менее 50% дозы дополнительного (аварийного) облучения населения. Специфические особенности агропромышленного комплекса свидетельствуют о его значительном потенциале при снижении коллективных и индивидуальных доз облучения (в отличие от ограничения доз внешнего облучения, что связано с большими экономическими затратами).

Почти 10-летние обширные исследования в области сельскохозяйственной радиоэкологии на территории, подверженной воздействию радиационной аварии на ЧАЭС, позволили собрать очень большой объем экспериментальной информации о поведении основных радиологически значимых нуклидов (^{90}Sr, ^{137}Cs, ^{239}Pu и др.) в системе выпадения - -почва сельскохозяйственные растения - сельскохозяйственные животные - рацион населения и динамике загрязнения сельскохозяйственной продукции на загрязненных территориях. Эта информация позволила разработать и внедрить в практику на всей территории, подверженной радиационному воздействию после аварии на Чернобыльской АЭС, систему ведения агропромышленного производства, направленную на получение всех видов сельскохозяйственной продукции с минимальным содержанием радионуклидов и снижение доз облучения работников сельского хозяйства и населения, проживающего в зоне влияния аварии.

Накопленные экспериментальные данные о поведении основных радиологически значимых нуклидов в агросфере и опыт внедрения системы защитных мероприятий в сельском хозяйстве на больших территориях могут рассматриваться базовыми при организации ведения сельскохозяйственного производства на территориях с различными типами радиоактивного загрязнения.

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MIGRATION OF RADIONUCLIDES IN BELARUS AND PROGNOSIS FOR THE FUTURE

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МИГРАЦИЯ РАДИОНУКЛИДОВ В БЕЛАРУСИ И ПРОГНОЗЫ НА БУДУЩЕЕ

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В докладе представлены результаты совместной работы, выполненной учеными Белорусской Академии Наук, Американского университета Тюлань и Республиканского центра радиационного мониторинга Беларуси. Работа выполнялась на основе теоретического и экспериментального исследования. Проводилось исследование миграции воздушным, водным и техногенным путем при нормальных условиях, аварийных ситуациях и стихийных бедствиях.

Для экспериментального исследования выявления закономерностей радиоактивного загрязнения рек на территории Беларуси был выбран водосбор реки Ипуть. Ипуть является самым большим притоком реки Сож.

С 1991 г. в контрольных створах г. Добруша и деревни Вылево проводятся ежемесячные наблюдения за поддержанием радионуклидов в поверхностных водах. Измеряется расход воды и уровень в створах. Ведется также отбор донных отложений. Проводится анализ слоя донных отложений из створа города Добруш и определяется активность цезия-134, 137, связанная с отдельными фракциями наносов. Были выделены четыре фракции: $>$ 1 мм; 1 - 0.5 мм; 0.5 ÷ 0.2 мм и $<$ 0.2 мм.

Содержание цезия определялось на гамма-спектометре. Погрешность измерения 30%.

В докладе проводятся подробные экспериментальные данные по удельной активности и гранулометрическому анализу.

Максимальное содержание цезия находится в донных отложениях перед водоподъемной плотиной. Удельная активность составляла здесь до 83600 Бк/кг, что соответствует уровню радиоактивных отходов.

Получены данные по распределению удельной активности по профилю реки. Цезий в основном переносится на фракции с диаметром менее 0,2 мм.

Приводятся данные по готовому выносу цезия с 1987 по 1992 г. Величина годового выноса цезия в этот период находилась в диапазоне 280-11 Ки.

На основании экспериментальных данных и обобщенного уравнения переноса американскими и белорусскими учеными были составлены концептуальная модель и программы для исследования.

В докладе также приведены данные по миграции нуклидов в озерах Беларуси. Миграция нуклидов воздушным путем прослеживалась на основе экспериментальных изучений и математических моделей.

Результаты исследований показали, что наибольшую опасность представляют пылевые бури и пожары в лесах. Были определены концентрации цезия, стронция и плутония.

Наибольшую опасность при пожарах представляют концентрации плутония в дымовом облаке. Приводятся данные для пожаров в различных местах.

Рассматриваются процессы переноса нуклидов при проведении сельскохозяйственных работ. Показано, что особую опасность представляют пылевые бури, особенно в местах эррозионных почв. Приводится карта опасных мест.

Дается оценка миграции радионуклидов из пунктов захоронения. Приводятся данные, полученные совместно белорусскими и шведскими учеными. Показано, что в ряде случаев возможно проникновение нуклидов в подземные воды, хотя удельная активность за счет разбавления не высокая.

Проведено исследование перемещения нуклидов за счет миграции животных и птиц и деятельности человека.

В целом идет процесс увеличения площади загрязненной территории.

На основании полученных экспериментальных и теоретических результатов были составлены нуклидные балансы для республики Беларусь. Приводятся новые данные по начальному периоду аварии, динамике изменения плотности суммарной миграции загрязнения, и оценка радиационного прогноза на будущее при различных стратегиях дезактивации и реабилитации. Даются вероятностные оценки доз.

DEVELOPMENT OF THE COMPLEX ATLAS OF CARTOGRAPHIC MATERIALS FOR THE CHERNOBYL EXCLUSION ZONE

XA9745842

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Chernobyl alienated zone (ChAZ) at present and in the visible future, being potentially dangerous territory for the inhabitants of Ukraine, still more or less actively utilized for industrial needs, and represents itself the unique polygon for the accomplishment of the complex diverse investigations aiming at the studies in different media of the processes and regularities, caused by the nuclear accident and by cessation of the intense economical utilization of the territory, as well as at the development of various measures concerning rehabilitation of different objects, areas, biosphere and a man himself.

Regarding the situation mentioned above, there should be distinguished following groups of problems, specific for ChAZ, which should be undoubtedly actual in the visible future: - estimation and prognosis of ChAZ radiation and radioecological state, regarding its influence on the ecological situation in Ukraine; - working out of strategic and tactical notions concerning the activities in ChAZ in accordance with "Chernobyl Alienated Zone Conceptions"; - adoption and realization of administrative decisions concerning the ChAZ support and activities in it, including evaluation and control over radiological consequences of ChAZ activities. Solution of these problems should be based on clear notions including the peculiarities of the structure and processes in different media, affected by the Chernobyl accident, as well as the distribution, intensity and direction of migration and secondary localization of radionuclides and other technogenous elements and compounds; the latter are determined by mutual influence of biological, geochemical, hydrological and other processes in interacting media.

The maps are one of the most effective and systematically organized methods of depicting accumulated knowledges about the structure and processes in separate media.

The complex cartographic analysis of these consequences could be properly accomplished only on the basis of revealing and regarding the environmental elements structure regularities and processes intrinsic for them and for the medium as a whole.

In 1995 on the initiative of ChAZ Administration the work was started aiming at compiling of the atlas of systematically conformed, mutually complementing maps, which would characterize:

- the process and the structure of the environmental elements system;
- the revealed consequences of the Chernobyl accident;
- their prognosticated estimations for separate media and ecological situation in general.

The preparation of the ChAZ conformed cartographic materials atlas should be based not on the mechanical combination of the previously constructed by different authors and for different purposes maps, but on the complex analysis and critical estimation of existing primary data, including the cartographic materials, and also on the data conforming, considering possible necessity of conducting additional field, analytic and other investigations, on compiling qualitative integral set of maps, which would describe our knowledges about natural and technical situation in the zone as full as possible. The purposes of operations planned are: collection and analysis of the existing materials, studies of the experience of the atlas
preparation, development of a series of scaled maps for atlas, elaboration of the methodological grounds of mapping, standardization of investigations metrological support, accomplishment of the necessary complex of experimental, regime, field, analytic, metodologic and other works; renewal of alienated zone topographic maps, development of the computer data base, preparation of the specialized maps with
corresponding explanatory notes for them, publication of "Atlas of Cartographic Materials for Chernobyl Alienated Zone". "Atlas" would be the necessary basis for:

- planning and accomplishment of further investigations to deepen our knowledges about radioecological, technogenous processes in the alienated zone, about rehabilitation potential of separate elements or objects of the environment;
- improvement of complex monitoring of alienated zone and surrounding territories;
- utilization of the atlas materials for more reliable estimation of alienated zone influence on the surrounding territories and inhabitants of Ukraine;
- development and adoption of the system of administrative decisions;
- the most complete presentation of cartographic information for the broad circles of the population in accordance with statements of the "Law concerning Chernobyl accident";
- presentation of the systematic and generalized cartographic information concerning ChNPP alienated zone to the governmental bodies of Ukraine, international organizations, governmental bodies of the foreign countries, the international public.

Regarding the character of the supposed users it is proposed to work out diverse purposeful variants of the atlas, distinguishable by the content and mapping scale.

The first group of users ("external users"):

- Cabinet of Ministers, Supreme Soviet of Ukraine, Administration of the President, international organizations, the governmental bodies of foreign countries, national and international informational organs, the inhabitants of Ukraine.

The second group of users ("internal" users):

- the alienated zone administration, research and industrial organizations, conducting the works in the zone or organizations, located outside the zone, but participating in the works inside the zone.

The third group of users:

- projectors, specialists involved in projecting and accomplishment of the works in the most contaminated "nearest" zone, where there are concentrated ChNPP, "Shelter" object, objects of the "Vector" complex, water intakes of ground water and other objects.

According to this typification the following sets of "Atlas" are intended to be compiled.

The first set of maps (basic) includes the whole territory of the alienated zone (within its new borders); the primary scale of maps is 1:100 000. However in separate cases the another scale of mapping could be grounded.

The second set of maps is supposed for more detailed representation of the most contaminated "nearest" zone, located in the central part of the ChAZ territory.

The most suitable mapping scale for this zone is 1:25 000.

The third maps set is advisable for the Chernobyl accident epicentrum area, including operation ChNPP ground and its surroundings. Regarding the requirements of scaled maps, the scale 1:5 000 is the most convenient for this set of maps.

The forth set of maps, as mentioned above, is intended mainly for "external" users. Concerning these circumstances, the majority of mapping is proposed at a scale of 1:200 000, which enables to depict practically the whole alienated zone in a sheets measuring 40*60 cm, so there would be easy to prepare this set of maps also in the form of table atlas. Regarding the maps content, this maps set, in general, is based on the first set of maps. However, they should be adapted for common (unskilled) people.

Spherical approach would be used in complex mapping of environmental elements and technogenous activities.

The objects of mapping in this zone are separate spheres, forming the environment (geobiosphere) - lithosphere, hydrosphere, biosphere, etc. In accordance with this approach natural-anthropogenous system (NAS) of alienated zone of ChNPP is formed by interacting and mutually penetrating anthroposphere and geobiosphere.

The latter, in their turn, are formed by spheres of higher orders. The maps are devided into groups, sub-groups, blocks and sub-blocks, corresponding to spheres of different orders. So, for example, in geoshere maps group the sub-group of geoshere maps is distinguished, including atmosphere block and geological block, which consists of 7-8 maps.

In sub-group of technogenous influence maps there would be depicted peculiarities and variety of radionuclides contamination of ChNPP territory.

There is also planned the development of maps set for ecological state and prognosticated ChNPP accident consequences and other kinds of technogenous activities.

With the purpose of systematization and integration of spatially oriented information for maps compiling and preparing computer variant of maps, there is planned geographical information technologies utilization.

As a result of planned works accomplishment there are supposed to obtain: the factual data base; the addressed sets of "Atlas" resulted in computer and published variant; the explanatory notes applied to the maps sets of the whole "Atlas" and to the maps; recommendations for the field and laboratory works execution, aimed at the further "Atlas" production, recommendations for planning, organization and execution of field works (for the period to 2000 and further).

The primary works concerning "Atlas" development are supposed to be finished in 1996-2000.

XA9745843

RELATION BETWEEN NATURAL AND ANTHROPOGENIC FACTORS IN THE REDISTRIBUTION OF RADIONUCLIDES ON THE 30 KM CHERNOBYL NPP TERRITORY, INCLUDING THE RESULT OF COUNTERMEASURES

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Before accident natural and anthropogenic ecosystems occupied about 90% of 30-km zone area, including 36% of forest ecosystem, ploughed lands - 28%, meadows and bogs - 18%. About 10% of total areas were occupied by ameliorated lands, separate water reservoirs - 2.8% relatively large area.

After 10 years after Chernobyl accident the lands structure was changed: areas of forest territories became larger (up to 12-13%). Areas of territories occupied by different technical constructions, roads were increased too. Modern structure of land-using of 30-km zone given in tabl. 1.

Table 1. Modern land structure of 30-km zone

Type of land	%
1. Forest lands	48.5
- pine	38.6
- leafy	9.9
2. Lands uncovered by forest	33.3
- fired forest - place	3.5
- cut forest	0.3
- bed lands, meadows (recent agricultural lands)	29.5
3. Other forest lands	1.1
4. Bogs, sand	2.6
5. Aqua objects	8.5
- cooling pound	1.2
6. Settlements, roads	6.0
Total:	100.0

Contamination of different objects of 30-km zone territory is very uneven, for instance variation of ^{137}Cs contamination of soil reaches the some thousand times (from 0.1-5 up to 10000 and more Ci/km^2).

According with different assessment, total amount (stock of radionuclides, Ci) of main doze-forming radionuclides, located on the territory of 30-km zone given in tabl.2.

Table 2. Radionuclides' stock in 30-km zone, kCi

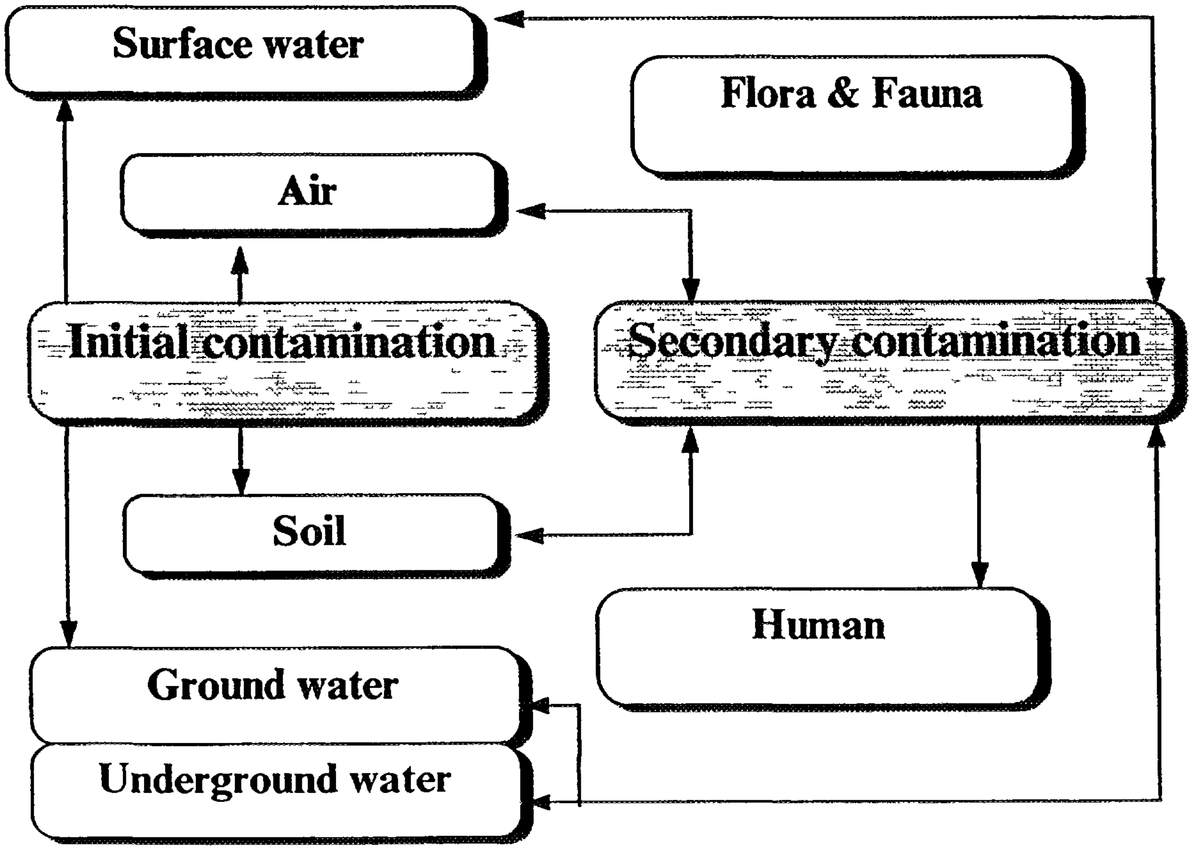
Territory	^{137}Cs	^{90}Sr	$^{239,240}Pu$
5-km zone	33.1	16.9	0.1
30-km zone (without 5-km zone)	93.6	84.4	0.8
including:			
forests	77	60	0.5
former agricultural lands	46	36	0.3
cooling pound of ChNPP	2.4	1.9	0.015
Place of Radioactive Waste Localisation	210	163	1.5

Radioactive contamination, fell down on a surface under natural and anthropogenic factors re-distributed in environments by different ways.

There are five type of migration, according with main factors, determining of migration of radionuclides on the territory:

- Wind (air) migration
- Biogenic migration
- Soil migration
- Water migration
  - * with surface water
  - * with underground water
- Anthropogenic migration

Principal scheme of migration processes is presented on a Fig .1.



Migration and re-distribution of radionuclides by air path-way

Initial contamination of territory was formed through air-path. Later the secondary resuspension (in significant amount) was important in central, high contaminated part of zone and it was caused by wind rising up of soil particles. Soil is a sources of secondary air contamination that is confirmed by relative similarity of radionuclides content of soil and air (table 3)

Table 3.

Relative contamination of soil and air in 1993 (%)

	Soil	Air
^{90}Sr	27	16.7
^{106}Ru	0.4	1.5
^{134}Cs	2.6	3.1
^{137}Cs	46	61
^{144}Ce	1.4	1.2
^{238}Pu	0.2	0.13
$^{239,240}Pu$	0.4	0.28
^{241}Pu	22	15.9
^{241}Am	0.3	0.24
	100	100

Values of resuspension factor in June of 1986 on a territory of 30-km zone were about $(0.5–2)\times10^{-8}$ $(Bq/m^3)/(Bq/m^2)$, that was significant less that was expected (10^{-5}). That is can be explained by following: radioactive contamination of territory was presented mainly as 'heavy' fuel particles, and subsequent gravimetric separation caused accelerative penetration of particles to deeper soil layers (that decreased resuspension factor).

Ten years after accident main part of contaminated area has become turfed, some part of radionuclides penetrated to deeper soil layers or had covered by forest litter or grass mat. It decreased resuspension factor, and now contamination of air is forming by small-dispersed aerosol fraction (less 3-7 μm).

Although the 30-km zone territory is characterised by presence of light sandy and sandy-loam soils, which contents less than 15% soil aggregates, stabled to deflation. However in present time secondary wind resuspension has as a rule restricted, local character (not more than tens and thousands metres) and very low parameters. In 1990 about 5×10^{-5} – 5×10^{-3}% of total contamination stock were risen up and resuspended monthly for a long distance.

Naturally concentration of aerosol increases remarkably during so-named 'dust-storm' and forest fire in 30-km zone. However these are not determine radioactive condition of surface air layer and in present time contamination of air is less than control limit level in 100-1000 times.

Biogenic migration of radionuclides

Flux of radionuclides through chain "soil-plant" is not so significant factor of re-distribution of radionuclides on the territory of 30-km exclusion zone. At the first that is because quantitative characteristics of radionuclides uptake by plants are very low (table 4). Only thousands part of total territory contamination can be drawn into biochemical circle. At the second, part radionuclides which was uptaken by plants as usual (if territory not in agricultural practice) after returned to soil after plants dying off.

Table 4.

Relative fluxes of ^{137}Cs and ^{90}Sr in agriculture ecosystem of Chernobyl 30-km zone with soil contamination density equivalent to 1 kBq/m²

	Mean Tf		Flux, Bq/m²	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
Winter wheat	1.24±0.3	3.26±1.1	0.21	0.55
Winter rye	1.85±0.4	3.78±1.1	0.15	0.30
Barley	0.37±0.1	0.94±0.3	0.05	0.13
Oats	0.32±0.2	0.63±0.14	0.03	0.05
Corn	0.16±0.1	2.5±0.7	0.05	0.75
Rape	11±4	34±22	1.32	4.1
Lupine	6.4±2.3	4.27±2.12	0.71	0.46
Potatoes	0.22±0.02	0.34±0.12	0.15	0.24
Natural grass	3.7±1.9	10.6±1.5	0.37	1.06
Milk products	0.89±0.05	0.03±0.01	0.07	0.002
Meat	0.5±0.2	0.06±0.02	0.35	0.04

Moreover, some biocenoses have properties to accumulate radionuclides inside local landscapes. At the first that is forest ecosystems, land impressions without water flow. According to calculations less than hundredth part of percents released from forest ecosystem.

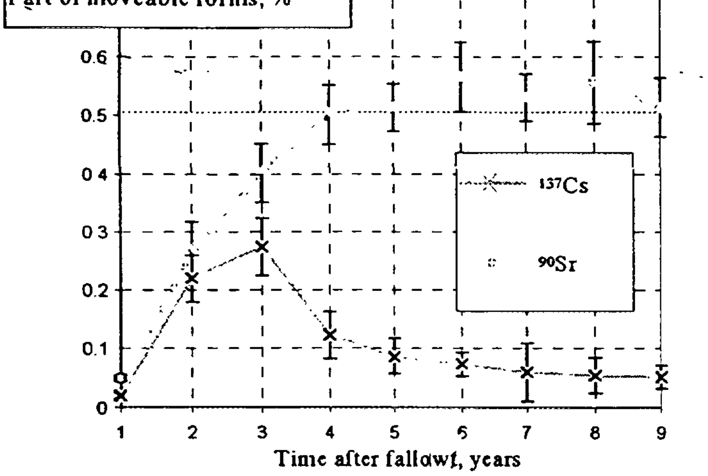
Soil migration of radionuclides

According with landscape assessment, about 40-45% of radioactive fallout located on territory of 30-km exclusion zone concentrated in such elements of landscapes were no possibilities with surface release of radionuclides. On these territories soil migration of radionuclides can take part with infiltrate water only.

During time the intensity of radionuclides infiltration through soil profile changed and was conditioned by increasing of moveable form content.

Concentration of moveable forms of radionuclides in soil is a result of two natural processes with different directions: release of radionuclides from fuel matrix and sorption by soil's minerals.

Typical dynamic of moveable form content in 10-cm layer of soil 30-km zone presented in fig.2.



According with results of lizimetrical observation no more that 1-2% of total radioactivity of 10-cm layer of undisturbed soil taking out with lizimetric water. Many-years dynamic of radionuclides (^{137}Cs and ^{90}Sr) in lizimetrical water shows well relation with content of moveable forms radionuclides in soil.

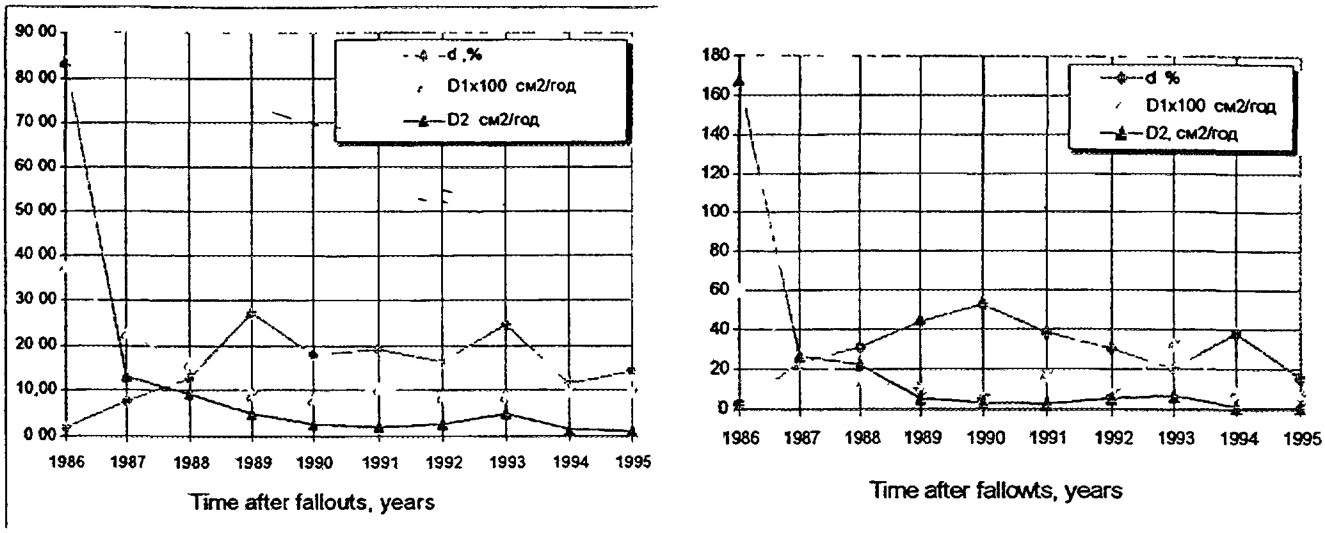
Parameters of vertical migration of radionuclides are often evaluated using a two-component quasidiffusion model of temporary change of radionuclides concentration in soil layers. According with the model the process of vertical redistribution of radionuclides on soil profile is a superposition of redistribution processes of two component of fallout: the radionuclides in composition of 'hot' particles and in water-soluble forms (so-named 'slow' and 'fast', respectively):

$$C(x,t) = C_0 \cdot \left(\frac{1-d}{\sqrt{\pi D_1 \cdot t}} e^{-\frac{x^2}{4D_1 \cdot t}} + \frac{d}{\sqrt{\pi D_2 \cdot t}} e^{-\frac{x^2}{4D_2 \cdot t}} \right)$$

The temporary change of quasidiffusion coefficients D_1 and D_2 (for soddy-podzol soil: D_1 changes from 0.08 to 0.37 cm²/year, D2 - from 1 to 84 cm²/year, for peaty soil: D_1 - from 0.05 to 0.60 cm²/year, D_2 - from 1 to 167 cm²/year) can be explained that an equilibrium of physico-chemical forms of the radionuclides and their stable analogies has not reached in soil. Any specific features of change of the model parameters (depending on soil type) are not observed.

The differences of ratio of 'fast' component depending on soil type have been found out: soddy-podzol soil - D_2 changes from 2 to 27%, for peaty soil - from 3 to 53%. It testifies that leaching of radionuclides from matrix of fuel particles is more intensive in peaty soil, than in soddy-podzol one.

On the pic. 3 many-years dynamic of migration parameters are presented.



a) soddy-podzol soil; b) peat-bog soil;

Picture 3. Dynamic of migration parameters for main type of soil in condition of 30-km zone

Water migration of radionuclides

Horizontal water migration

Water-erosion processes lead to forming of liquid and solid flowing from upper landscape elements. As a rule these flowings are negligible and depend on steepness of slope. The maximum volume of the flowing and intensity of carrying out of small soil fractions take place in February - May, i.e. due to melted water and rain, before forming of grass vegetation. According with different assessment the carrying out of ^{137}Cs with liquid and solid flowing varies from 0.05-0.005% per year.

As well as territories, from which water stock collects, bottom sediments of reservoirs are sources of radionuclides for water. The stocks of radionuclides in bottom sediments of cooling pool of ChNPP and Kievsky reservoir are presented in tabl. 5.

Table 5.

Stocks of some radionuclides in bottom sediments and on waterplate of main reservoirs, Ci

Reservoirs	Square, km^2	^{137}Cs	^{90}Sr	$^{238,239,240}Pu$
Kievsky reservoir (bottom sediments)	922	2600	700	
Cooling pool (bottom sediments)	22.9	4600	770	21
Krasnyansky starik (waterplate)	23.4	7000	4300	175
Benevsky starik (waterplate)	10	375	354	18

Leaching rate of ^{90}Sr from bottom sediments of cooling pool is estimated as 45 Ci/year or less 1 % from total stock. Carrying out of ^{137}Cs and ^{90}Sr with river Pripyat in Kievsky reservoir is shown in tabl. 6. The high values for ^{90}Sr in 1991 are determined by ice jam and flooding of the waterplate in January-February 1991. As result an additional release of ^{90}Sr reached 90 Ci.

Table 6.

Carrying out of ^{137}Cs and ^{90}Sr in Kievsky reservoir with river Pripyat in 1986-1993

Year	Average outlay of water during year, m^3/sec	Carrying out, Ci	
		^{137}Cs	^{90}Sr
1986	302	1785	746
1987	246	344	280
1988	411	256	506
1989	392	174	241
1990	409	125	273
1991	442	78	389
1992	295	52	112
1993	597	103	426

Radiation state of underground water in places of temporary localisation of radioactive waste as well as dam of cooling pool of ChNPP causes great trouble. Concentrations of ^{90}Sr are more higher there, than in river Pripyat (tabl.7).

Table 7

^{90}Sr concentration in ground water, pCi/l

Place	November 1992	November 1993
"Red Forest", Strojbasa	19-1200	530-4000
"Red Forest", Yanov	5-32	15-88
Dam of cooling pool	47-380	220-500

Thus the water way of radionuclides migration and redistribution is one of main.

Conclusion

To solve problems of decreasing and liquidation of Chernobyll accident subsequent assessment of intensity of natural processes (wind, rain, accumulation properties and migration factors of soil, chemical and nuclear-physical characteristics of radionuclides) is important criteria of action variants, including assessment of engineering measures efficiency. On a base of comparison efficiency and availability of planning measures evaluates expedient intervention levels too natural processes. In this direction the experience of liquidation of ChNPP accident subsequences gives some practical lessons which can illustrate necessity detail assess and analyse of future results from point of wiev loss and acquisition ("cost-benefit"). Ecological and economical insolvency of some countermeasures of first period (1.5-2 years after accident) was evinced clearly.

There are large-scale and expensive countermeasures of marked period:

Dust-suppression in forest and agricultural lands with using of different artificial polymers, "MM-1", waste of chemical (latex) manufacturing and paper production was not effective measures which did not change radioecologycal situation on a large squares but spent a lot of financial and human expenses.

Building of dams and dikes with ceolite in small rives (132 stick) decreased concentration of radionuclides in water on 3%. But as negative result after increasing of underground water levels 2000 hectares of foorestand was death. There are 120 dike were destroyed after flood in 1987.

"Burring" of "red forest" was done on a square 600 he to decontamination of territory, decreasing external irradiation and to prevent forest fire and distribution of radioonuclides out of 30-km zone. As a result, radionuclides contented in forest litter, were removed to level of underground water and have now large moveability in comparison with initial location.

In compare different ways of radionuclide migration in 30-km zone that is possible to mark following:

- initial radionuclide distribution on a territory of 30-km zone caused in principal by natural processes, landscape and geophysical properties of territory and character of fallout.

- secondary anthropogenic redistribution (flux) of radionuclides was connected significantly with attempts of territory decontamination which lead to change of radionuclide localisation, concentration of radionuclides in different places (about 380 kCi)

- there are more then 600 kCi of long-life radionuclides covered of 30-km zone territory (240 kCi falled out on a surface of soil and reservoirs), which will be subjected by physico-chemical influence, that lead to redistribution and migration through environments

- intensive stage of radionuclide redistribution in natural (environmental) objects are finishing and now processes which speed compared to half-life period of radionucllides are going.

RADIOBIOLOGICAL EFFECTS IN ORGANISMS OF PLANTS AND ANIMALS EXPOSED TO IONIZING IRRADIATION IN THE CHERNOBYL NPP ZONE

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Radiation effects in pine forest

Influence of IR on forest ecosystems most clearly revealed itself near the Chernobyl NPP (ChNPP), where magnitudes of absorbed doses reached 'lethal' values, as applied to conifers. Main contribution to absorbed dose was due to beta-radiation of short-living radionuclides. To largest extent the radiobiological effects appeared at injured plantations of pines and firs. Nevertheless, during the first year maximum absorbed doses influenced also on leaf-bearing trees (birch,alder,asp) which then rehabilitated themselves completely.

Depending on degree of radiation effect, 5 zones of injury were marked out (Table 1). Criteria for that were as follows: absorbed dose, degree of affection of tree crowns, phytomass increase, as well as category of plantation condition as a whole.Weak influence took place at exposure dose (in May - June , 1986) not less than 20 mR/h, the cumulative dose being more than 0.1 Gy (during the period of sharp irradiation). Visible damages of trees were not observed. In some cases the effects of radiostimulation of growth became apparent, but not very expressive. The situation had been normalized here already during the first year.

In the zone of weak effect one could note delay of sprout&needle growth during the first after-accident year and morphological abnormalities in vegetative organs. Action of radiation factor revealed during two years, then growth of trees normalized completely.

In medium injured stands the cumulative absorbed dose was 1 to 10 Gy. Considerable inhibition of growth of sprouts and needles was noted, as well as a drop in radial growth, damage of crowns, numerous morphoses and death of a part of the trees (mostly of low classes of growth). That caused pronounced worsening in the condition of the tree stands. Damage in regenerative sphere of pine was marked. Processes of reparation in those plantations proceeded for three years. Irradiation accelerated differentiation of trees in the stand. It led to some decrease in completeness of plantations. By now normal growth and development of trees have restored here too.

Table 1. Dynamics of condition of pine forests exposed to radiation

Degree of injury, absorbed dose, Gy	Condition in 1986	Period of restoration, years	Current condition (1995)
No signs of injury, < 0.1	Changes in growth	1	Complete restoration
Weak, 0.1 to 1	Inhibition of growth, morphosis	2	Complete restoration
Medium, 1 to 10	Death of separate trees, inhibition of growth, morphoses	3	Complete restoration
High, 10 to 60	Death of groups of trees, complete inhibition of growth, decrease in radial increment	Not complete. Change of vegetation community goes on.	Needle/leaf - bearing plantations are forming.
Total death, >60	Yellowed needles, death of pine stands, invasion of vermin	Change of vegetation community	Leaf-bearing plantations are forming

Radiobiological effects found their most clear expression in strongly injured plantations. Practically complete oppression of sprout & needle growth, death of buds and of a part of the crown, defects in the structure of wood, death of considerable part of the tree stand and complete inhibition of reproductive functions took place. General inhibition of the stands led to death of the most part of the trees. But survived ones, with at least 5 to 6 growth points remained, gave a good growth next year, having increased significantly the size and mass of needles (Table 2 and 3).

In succeeding years two processes counteracted each other here: post-radiation restoration of survived trees and degradation of tree stands. Deterioration of tree stands led to mass reproduction of vermin. Two years after injury, when radiation factor already did not define survivability of trees, the condition of strongly damaged plantations depended on factors of forestry and

Table 2. Reaction of 30-year old pine trees to acute radiation

Degree of plantation injury	Quantity of buds on medium tree, %		Increase in crown phytomass of one tree, %		
	1986	1994	1986	1987	1994
High	<5	55 - 75	<5	10 - 25	40 - 60
Medium	5 - 25	>200	5 - 30	25 - 50	100
Weak	25 - 75	>200	30 - 70	50 - 95	100
No signs of injury	>75	>200	>70	>95	100

on development of vermin focal points and root sponge. They determined further degradation of tree stands. It continues now too. Under the cover of almost perished forest, a large self-seed of leaf-bearing trees appeared. In the future a birch tree stand will form here, having some separate survived specimens of pine on its territory.

On plantations where absorbed dose was more than 60 Gy the loss of trees succeeded in very short period of time. These areas served as a base for invasion of secondary vermin that propagated then to adjacent areas. Now these stands of trees already do not exist. In their place some "meadow communities" have formed (partly), and on the major part a self-seed of leaf-bearing trees appeared, and formation of new stand of trees began.

At the present time there are no morphological signs of injury of pine stands observed on the whole territory of the zone. Separate breaches in the growth of highly injured tree stands, in particular big sizes of needles (Table 3), were caused by rather factors of forestry than of radiation influence.

Table 3. Relative size of needles in stands of trees having injuries of different degrees

Degree of injury	Size of needles, % of norm		
	1986	1987	1994
High	66	182	115
Medium	65	158	100
Weak	91	142	99
No signs of injury	96	97	99

At the same time an increase in quantity of the morphoses in young pine trees transplanted on the former place of 'red forest' was fixed in 1995. The cause of the phenomenon is unclear yet, and growth of the plantations on the areas with high density of contamination needs more careful control.

The test cultures were created in different regions of Ukraine in 1988 to 1994 from the seeds gathered on damaged plantations.

Higher frequency of morphoses was observed during the first year of growth of seedlings but thereafter the deviations in evolution were absent, and no dependance between the degree of damage and the growth of test cultures was found.

IR exerted more deep and prolonged influence upon the reproductive sphere. In early years the plantations having high absorbed doses demonstrated significant destructive processes in plastides being reflected in damage of chlorophyll-protein complex, decrease of chlorophyll and increase of carotinoid quantities. The plantations exposed to low degree of irradiation, on the contrary, demonstrated an increase in the content of chlorophylls and in the size of structural elements of the pigment system. Now direct dependance between IR absorbed dose and accumulation of pigments is not observed. Sensitivity of vegetative and generative tissues of a pine tree to irradiation depending on the phase state of cells appeared to be different: one of the cells in the rest phase is lower than one of them in the phase of active cell division. On being irradiated with sublethal doses, the tissues of vegetative organs recover in 1 to 2 years after irradiation, and to normalize the processes of formation of generative organs, it is needed from 2 to 6 years and more, depending on the dose of irradiation.

Damaged plantations demonstrated a delay in beginning the reproductive processes in early years after the accident. In 1995 the beginning of meiosis was noted simultaneously on all areas. Only the plantations with high density of contamination show some delay of separate phases of meiosis. Investigation of the breach frequency in separate phases of meiosis showed that the quantity of anomalies in metaphase - 1 and - 2 at high density of contamination was 3 to 4 times more than in the control group.

The level of chromosome breaches in 1995 appeared to be practically the same as in 1987, but the frequency and types of aberrations considerably changed. In 1987 the aberrations of the chromosome stick-together type were observed most frequently. They were caused by a great number of ruptures when the objects have been exposed to acute external irradiation. In 1995 this type of aberrations was not revealed, but the bridge-type ones have been seen very often. The delays of chromosomes in anaphases were met with near-identically in frequency in 1987 and 1995.

It is interesting that the lowering of the level of breaches in meiosis took place in 1988 (2 to 3 times). In 1995 the original level of breaches was restored, but at the same time the frequency of different types of breaches changed.

A decrease in the quantity of breaches in 1988 can be explained by restoration of intercellular protective system due to disappearance of acute irradiation. Further, as the plants accumulated radionuclides, inner irradiation evidently became even more important factor in the origin of chromosome breaches.

In the whole, at present time the viability of pollen is practically the same on all plots with slight decrease in plantations having high density of contamination. But the length of pollen tubes in these cases is obviously less and correlates with reduced quantity of starch and high specific activity of pollen. Most likely, the disturbances revealed in the process of formation of microgametophytes did not lead to their considerable loss but disrupted normal metabolism of pollen grains.

Researches of last years showed that the ecological factors (especially climatic ones) could significantly affect development of reproductive sphere of pine and modify the influence of radiation. In 1995 a decrease of relative/absolute gametophyte survivability took place (particularly on plots having high density of contamination) due to summer drought observed now in its second year. It was the worsening of weather conditions that caused an additional loss of seed-buds in the amount of 13 to 15 per cent.

Effects of irradiation in minks

Animals being under chronic influence of ionizing radiation (small doses) showed that clinical/ laboratory characteristics of most of species, describing functional state of different organs and systems, are within their physiological standards. However, experimental researches (carried out at tissue/cell/subcell/ molecular levels) allowed to reveal a number of forming radiobiological effects.

A complex of pathological changes revealed in minks which were kept 2 to 3 years near the ChNPP and have received a dose of internal irradiation (from incorporated radionuclides) of about 29 to 39 Rem.

Using the electronic microscopy in analysis of brain cell elements and of ultrastructural organization of vessels showed that the changes in neurons were rather various, and both initial (reversible enough) and non-reversible ones. In this case the changes in neurons, glial cells and walls of intra-brain capillaries are closely linked together and lead to disturbances in functional state of the complex 'neuron-glia- capillary'.

Particularly expressed are the changes in neurons in the area of hypotalamus. Due to intracellular oedema, the quantity of dystrophically destructive neurons in hypotalamus and nuclear/cytoplasmatic index of hypotalamus neurons in experimental animals are almost twice as large, and ones of cortex neurons are only 1.5 times as large against the control. Because of this a decrease in quantity of unchanged neurocytes is observed.

Against the background of morphological changes decrease of protein level in hippocamp, striatum, middle brain and cortex has been reliably established. This witnesses that there are non-reversible disturbances in a number of central mechanisms, regulating critical functions of organism.

Animals that were for a long time (2 to 3 years) in the zone of the ChNPP accident showed significant shifts in neurochemical regulation of endocrine system, as well as ultrastructural evidences that there existed stimulation of secretory activity of cortico-tireotrope cells of adenohypophysis at simultaneous deceleration of secretory function of gonadotropocytes. Disturbances of central regulation of endocrine system reveal at the level of periphery glands in the following way: in thyroid glands one can observe distinct activation of secretory process against the background of hypertrophy and hyperplasia of follicular and parafollicular cells; in the cortex of adrenal glands a growth in functional stress of adrenocorticocytes is traced and (in parallel) destructive changes develop in these cells and in microcirculatory flow that leads to weakening of adaptation reserves and of hormonal activity of adrenal glands. One observes weakening of testosterone generation and disturbances in the processes of formation of gametes, influencing negatively on reproductive function of males. Increased number of molecules of products of lipide peroxidation 'sewn together' with proteins of cell membranes has been found in liver, thyroid, skin and testicles of minks. That witnesses exhaustion of reserves and of antioxidant protective systems in these organs.

At the study of genotoxicity of radionuclides incorporated in the cells of bone marrow and periphery blood lymphocytes of minks it was established that the irradiated animals are characterized by decrease of a part of cells being in the G0/G1 phase of the cell cycle, followed by compensatory increase of a part of lymphocytes being in the S- and G2/M- phases. This testifies less intensity of reparatory processes in animal tissues being under internal irradiation than in ones of control animals.

The experimental animals demonstrated the worsening of strength characteristics of bone/cover tissues. Experimental group of animals has a strength limit index of bone tissue of limb skeleton elements more variable than one of control group. Histologic researches found (in bone tissues) as follows: a decrease in specific volume of spongy bone in metaphyses and epiphyses; intensification of resorptive processes; the areas where a bone matrix was substituted for fibrous tissue; differences in correlation between the processes of osteopoiesis and resorption at the formation of a compact.

The revealed changes in the amino-acid composition of bones and of skin of minks being 2 and 3 years old are monodirected but older animals have these changes more expressed. Changes in the content of oxilysin, lysin and oxiprolin are due to formation of intra- and intermolecular 'sewn pieces', and changes in the content of asparagin acid and of glutamin one are due to the changing charge of a molecule. Quantitative changes in a number of other aminoacids have an effect on stiffness of collagen spiral and also on the quantity of domains 'arg-gli-asp' that cause adhesion of cells on a collagen fibrilla. Apparently, these disturbances are at the bottom of weakening, first, of bone tissue stiffness and, second, of fixation of hairs in hair bulbs.

Taking into account a great number of signs we are able to make a conclusion that the state of hyperadaptasis appearing in animals is similar to that one developing in the organism in aging.

Consequence of irradiation in cattle

Since 1988 radiobiological investigations are carried out at an experimental vivarium (the 5-km zone ChNPP) on cows. The herd consists of some groups:

- A - four animals, which inhabited in nearest territory around ChNPP during 1986-1987 and were cought in November of 1987; B - cows brought in the vivarium from settlement Polesskoe (abroad 30-km zone); C - first generation from group A; D - first generation from group B.

According with our calculation in 1986-1987 group A received dose about 2.5 Gy on whole body, 10-11 Gy - on gastrointestinal tract and 130 Gy on thyroid gland. During subsequent years accumulated dose didn't exceed 0.02 Gy/year oon whole body and 0.1-0.3 Gy/year on gastrointestinal tract.

In 1989 a first generation from group A was got and more 40 calves of first-third generation were got by 1996. Physiological state of the experimental cows was investigated by different hematological, biochemical and cytogenetic methods.

The main hematological indices (quantity of erythrocytes, leukocytes, hemoglobin) were in physiological limits. Nevertheless, lymphocytes quantity was higher norm (up to 60-65% before 1993). Granulocytes contained eosinophils (13-20%) and basophils (up to 1.5%). Compaund of neutrophils testifies about some inhibition of blood-forming. Hard identificated and abnormal cells are observed, such as: limphocyte-similar oone with obvious basophilia of cytoplasm and exocytos of little granules; apoptose of cells; aglomiration oof nucleus segments of eosinophils. Some of these perculiarities are known as usual for chronic irradiation. By 1996 the amount of abnormal and hard identificated cells has decreased. The decrease of lymphocytes quantity has been noted too. Basophilia has disappeared. Expressed eoosinophilia are observed for all animals.

The most remarkable radiation effects were found out when we investigated prooxidant and antioxidant systems. Methabolitic indices of the animals blood (group A) characterised by following perculiarities: higher activity of antioxidant systems on background of weakening of pro-oxidant one, accumulation of secondary and final products of lypide peroxide oxidation (POL), hemolitic resistance of erythocytes (HRE). First generation of the group A had most expressed deviation from norm: highest level of POL activity, strain of antioxidant system, lowest HRE. The animals of group B had relative stable indices, and internal protective mechanisms of group D provided them a most low level of POL and highest HRE.

During last 3 years processes of POL in groups A, B and D normalized. First generation of group A differed by continuation of accumulation of POL products and lowest HRE (blood-forming system had signs of inhibition). Antioxidant system has normalized in groups A and B and reached equilibrium with activity of prooxidant system. In group C the antioxidant system kept strained. In first generation of group B the some higher activity of antioxidant system was observated on background of relative low level of POL. This group has most high HRE.

During all years high quantity of serum protein and low immunoglobulin was usual in all groups.

Chronic irradiation of the cows organisms reflected on cytogenetic perculiarities of them. So, quantity of aberrant cells (lymphocytes) varied: 0-20% in 1991 and 0-5% in 1995. In first years we observed different types of abirration: chromosome, chromatid and genom one. The chromosome type dominated in 1991 (3.45%) (chromatid - 2.67%). Genom aberrations were represented by tri- and tetraploids. All types of aberrations had bigger frequency than control. The most higher level of aberrations was in group C (7.4%) and group A (6.1%). For most groups such kind of abirrations as dicentric was noted before 1993. In 1995 it kept only in lymphocytes of group C. The frequency of aberration has decreased in 1995 and chromatid aberrations dominated.

Thus, the performed investigations shown, that type and degree of radiobiological effects depended on value and duration of irradiation and onthogenetic stage of animals, when the dose were received. The most deeper changes took place in organism of first generation of cows, which inhabited in nearest zone of ChNPP in 1986-1987. Protection systems of organism of their parents allowed more successfully to maintain homeostasis. Long strain of different systems caused pathological specific and non-specific aberration. Nevertheless, during 8 years of the observation no one death was noted and general state of the animals normalized constantly.

XA9745845

TECHNOLOGY OF LONG-TERM LOCALISATION OF SOILS CONTAMINATED WITH RADIOACTIVE AND HIGH-TOXIC SUBSTANCES

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1. INTRODUCTION

The world experience shows that great process accidents lead to hundreds of thousands hectares of surface contamination with high-toxic substances that causes the areas conversion into active sources of secondary contamination [1]. For example after Chernobyl accident contaminated more then 2000000 ha. territories. Nuclear installation decommissioning can also result in such contamination, that can as well be registered at the places where industrial wastes are piled up or stored.

2. METHOD

In connection with that there arises the problem of contaminated soils long-term prevention from wind erosion. The soil particles are known to contain silica on the surface of which there are silanole groups [2] able as a result of dissociation to acquire negative charge and to come into chemical and electrostatic interaction forming connections with various compound classes able to act as cationes. As it is known, polyelectrolite complexes [3,4] are classified among such compounds.

Interpolyelectrolite complexes (IPEC) are the products of interaction of the two oppositely charged polyelectrolites - polyamone and polycatione. Polycatione forms on the soil surface the ion connections with silanole groups located on the silica surface [4-7]

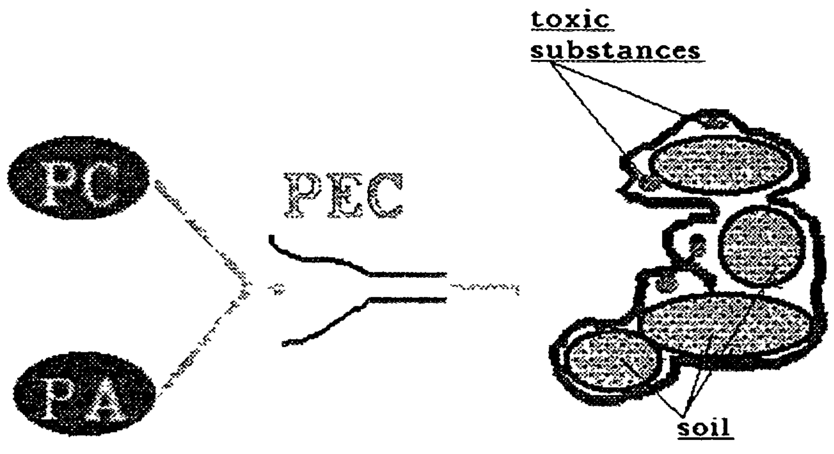

Fig. 1 Formation of soil-polymer layer.

In our research we used: potentiometric titration, IR-spectroscopy, radiometric, aerodynamic chamber, cryogenic chamber, aerosol laser meter.

3. RESULTS

While creating complexes to provide the optimum soil fixation we have investigated by optical microscopy the protective polymer soil layer microstructure. The following types of connections arising in stabilised polymer soil layer that depend upon the nature of polymer and its amount, have been found:

a) continuous sands gluing together with impenetrable soil-polymer crust layer. Here every sand independently on its size, is filmed with thick (5-10 microns) polymer layer, moreover, the polymer occupies all the space among sands, forming thick impenetrable film.

b) sand particles gluing together with polymer only at their contact places. Water filtration and aeration of bottom sand layers take place through the sand particles free interspace.

c) connection of sand particles of different size, that are on considerable distance (from a few microns up to 1-2 mm) from each other with long and thin (about 20 microns) filaments-bridges.

d) adhering of small-size particles (from less than 5 microns up to 250 microns) to the surface of larger sands (more than 700 microns). Such adhering-attracting of fine disperse particles takes place during the polymer drying out due to the sand particle enveloping with drying solution. And fine disperse particles are picked up by such a solution from the space, formed by loosely located large particles, attracted and glued to the surface of large particles.

Polycatione and polyanione interaction on the soil particle surface leads to the formation of soil-polymer crust layer insoluble in water but permeable and gas-penetrable. The presence of hydrophilic as well as hydrophobic bridges in the IPEC structure leads to the most optimum bond of the soil particles. As a result of wide-scale works carried out in the site of the Chernobyl NPP since July 1986 the polymer soil coatings based on the complexes with commercial labels MM-1 and MT-1 were established jointly with Moscow State University to have the most acceptable protective properties.

When the soil is being coated with working solution that is an agues polymer solution with 2-4% concentration, a soil - polymer crust layer with 3-5 mm thickness is formed on surface. The polymerisation time depends on the soil moisture content and temperature of surrounding air, the polymerisation is practically completed when the layer is dried out.

The complexes developed have passed laboratory and field tests in the site of the Chernobyl NPP. The behaviour of complexes and protective coatings has been studied under laboratory conditions at negative temperatures down to minus 40^{o}C. The protective coatings are shown to retain their properties at negative tempera ture as well as after thawing. The protective coatings microstructure investigations by optical microscopy have shown that no changes occur when the freezing-thawing cycle is repeated many times.

Radioactive substance dust carry-over has also been evaluated under laboratory conditions at air flow rate values equal to 7.5, 10.0, 15.0 and 20.0 m/s. The results of measurements show that the dust carry-over value is practically independent on the air flow rate and for the specimens treated under laboratory conditions it is on the level of measuring apparatus sensitivity and measurements error.

IPEC and their-based coatings resistance to gamma-irradiation is studied at the installation with Co-60 source at gamma- irradiation dozes up to 10^6 Gy. It is shown that the IPEC holding ability doesn't decrease within the indicated dose range.

During the field tests in the site of the Chernobyl NPP the following values for specific aerosol activity, in the air flow over specimens, are obtained using laser analyser of aerosol sizes (see table I).

The rate of the complexes flow depends on their properties, type of the soil and its moisture content.

The experience of works on dust suppression in the site of the ChNPP has shown that the formation of the turf layer (biological chemical fixation of the soils) is the most promising way for prevention of the dust carry-over. In connection with that a combined technology for the soil fixation with the simultaneous surface cladding with the dust suppressing MM-1 and MT-1 complexes as well as perennial herbs seeds, has been developed jointly with VNIIvodpolymer. This technology has success fully tested within the site of the Chernobyl NPP .

To improve the uniformity of the soil surface treatment with the dust suppressing complexes, to provide the possibility of the soil simultaneous treatment with the complexes and seeds of herbs and to reduce the air aerosol contamination conducting works in the site of the Chernobyl NPP , an experimental prototype of sowing-irrigating machine PPME-8 has been developed jointly with VNII vodpolymer.

Table I. The results of specific aerosol activity measurement in the air flow over the specimens of the soil and protective coatings on the base of MM-1 and MT-1

N	Activity before treatment 10^4 Bg/ m^3	Activity after treatment 10^4 Bg/ m^3	
		MM-1	MT-1
1	18 02	1 48	0 37
2	138 75	6 66	11 84
3	361 12	14 06	24 05
4	208 68	14 80	4 81
5	663 41	15 54	15 17

Operational characteristics of the MM-1 and MT-1 complexes are given in table II

Table II. Characteristics of the protective polymer soil crust layer

N	Parameter	MM-1	MT-1
1	Reduction of the air aerosol contamination as a result of treatment	10-100 times	20 times
2	Rate of the complex flow, l/m^2	1 0	1 0 - 1 5
3	Thickness of the protective polymer soil crust layer , mm	3-5	4-6
4	Protective layer resistance to rain, mm	not less than 600	not less than 600
5	Resistance to mechanical attack, kg/sm^2	3-4	5 0
6	Possibility of joint application with perennial herbs seeds at the soil biological chemical fixation	possible	possible
7	Service-life of protective coating, not less than, months	12	12
8	Toxicity LD/50, g/kg	Scarcely toxic 44 98	Scarcely toxic

Technical characteristics for experimental prototype of sowing-irrigating machine PPME-8 .
Production rate at continuous operation, ha/h 1.1-2.43
Operating width, m 8.2
Working solution flow rate, l/m^2 0.5-2.0
Ultimate angles for the surface bein treated, degr. +45 -30
Personnel 1 tractor operator

Fig. 2 Tests of PPME-8 in the Chernobyl NPP site.

The PPME-8 tests have been conducted in the site of the Chernobyl NPP in 1989. The following characteristics distinguish the machine from technical means having been used before:

-uniformity of putting dust suppressing complexes and seeds of herbs on the soil surface;
-great width of the strip being treated;
-high cross-country capability;
-absence of dusting at sowing seeds of herbs.

Both complexes have passed successful tests in the site of the ecological calamity of the Aral sea. The tests have shown that with the help of these complexes one can achieve the reduction of great salt-contained sand masstransfer from the surface of the dried-up sea ground. It was mentioned that the MT-1 complex is more stable under the conditions of the great salting.

4. CONCLUSIONS

1. The method, interpolyelectrolyte complex-based polymer compositions and technology for the contaminated soil prevention from wind erosion, have been developed;

2. The operational characteristics for the developed protective compositions have been determined eliminating of consequences of the Chernobyl NPP accident and in the region of ecological calamity of Aral sea;

3. An experimental prototype of sowing-irrigating machine has been developed and tested while eliminating the Chernobyl NPP accident consequences.

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POST-ACCIDENT ENVIRONMENTAL RADIOMONITORING IN THE VICINITY OF THE CHERNOBYL NPP

XA9745846

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INTRODUCTION

After the Chernobyl Accidents has happens, the vicinity around the fourth reactor unit, destroyed after explosion, has become the largest outdoor laboratory, where the mankind's knowledge concerning the radionuclides behaviour in the environment can be essentially tested and improved. An international group of scientists from the Ukraine, USA and the IAEA fellows from Brasil, Kenya, Syria and Iran as participants of Summer School on environmental monitoring, took participation in field exercises to investigate radioecological situation inside 30-km Exclusion Zone at three different sites: two fields and one forest with different levels of contamination.

The present radioecological situation inside the 30-km Exclusion Zone is mainly determined by the ^{137}Cs + ^{134}Cs, ^{90}Sr and transuranic elements as well [1]. The international group divided into teams and performed gamma and beta surveys, in-situ gamma-spectrometry and vegetation and soil sampling in contaminated field and forest locations.

The aim of this work was to investigate the peculiarities of measurement at different sites and to develop recommendations on group-made environmental monitoring.

EXPERIMENTAL

Sites description

Three sites were established for a training on environmental monitoring Site 1 [2] was a part of field used before an accident has happened to grow agricultural cultures This field site was large, open, flat and grassy terrain of clay soils. Site 2 represents a forest ecosystem and was situated in 50 meters from an edge of pine forest. Site was quite flat with typical vegetation for a given locality Site 3 was situated 100m in southern direction from Site 2. But when all measurements have been conducted and activities calculated, it was found, that the ^{137}Cs activity distribution was uniform. It means the deep cultivation took place after radioactivity fallout. That is why the results, concerning Site 3 were omitted from the next consideration

Fig 1 shows the locations of sites relatively to Exclusion Zone

Measurement technique

Gamma - survey

Within selected areas (Fig.2) dose rates and gamma flux were measured at two different heights (0 05m and 1m) (Fig 3, 3A) . Ten measurements for dose rate and for gamma flux were done at each of the points and ten measurements only for dose rate were done around the centre of the selected area The measurements were performed by a GM tube dose rate meter which an acceptable main error limit (95% confidence interval) of ±(30+1.0x[Unit]/*R*)%, (*R*-dose rate in units of the corresponding subrange -mR/h or R/h) and a scintillation detector with a range from 0 to 10000 s^{-1} for dose rate and gamma flux respectively

Beta - survey

To determine the beta - surface contamination in the selected area, beta - radiometer with thin-walled cylindrical type GM-tube have been used Two measurements (one - with bare detector, second one - with detector, severed by stainless filter thick enough to stop electrons) have been conducted The difference of readings of both measurements was interpreted as an electron contribution The frequency histograms are given in Fig 4 for both sites

In-situ gamma spectrometry

As well known to determine the inventory of ^{137}Cs (activity per unity area) through a combination between in-situ measurements and soil sampling , for undisturbed after fallout land a square area at least of 10x10m far away from roads is needed

In practice, the characterisation of contamination of a site may involve in situ gamma spectra measurements in conjunction with soil sampling. It also reduces the number of samples to be collected and gives a representative average activity value for a large area of ground. In-situ gamma measurements were done in the area at points in a height of 1m using the Silena Nuclear Processor - SNIP 201N/W and NaI(Tl) detector. The gamma spectra obtained had a post-treatment using the Silena Simcas (Computer-based Nuclear Analysis System) in order to grant a better result Figure 5 presented an example of the in-situ gamma spectra obtained

Soil sampling

For soil sampling a top soil cutter having 6cm diameter and 20cm height has been used 10 cores were taken to make a single sample Then 20cm layer was divided into 5 subsamples, representing 0-2cm, 2-5cm, 5-10cm, 10-15cm and 15-20cm layers The subsamples collected for each measurement point were sealed in double-walls plastic bags A sheet of paper, containing all the information about sample (identification, geographical position, etc) was located between plastic bag walls

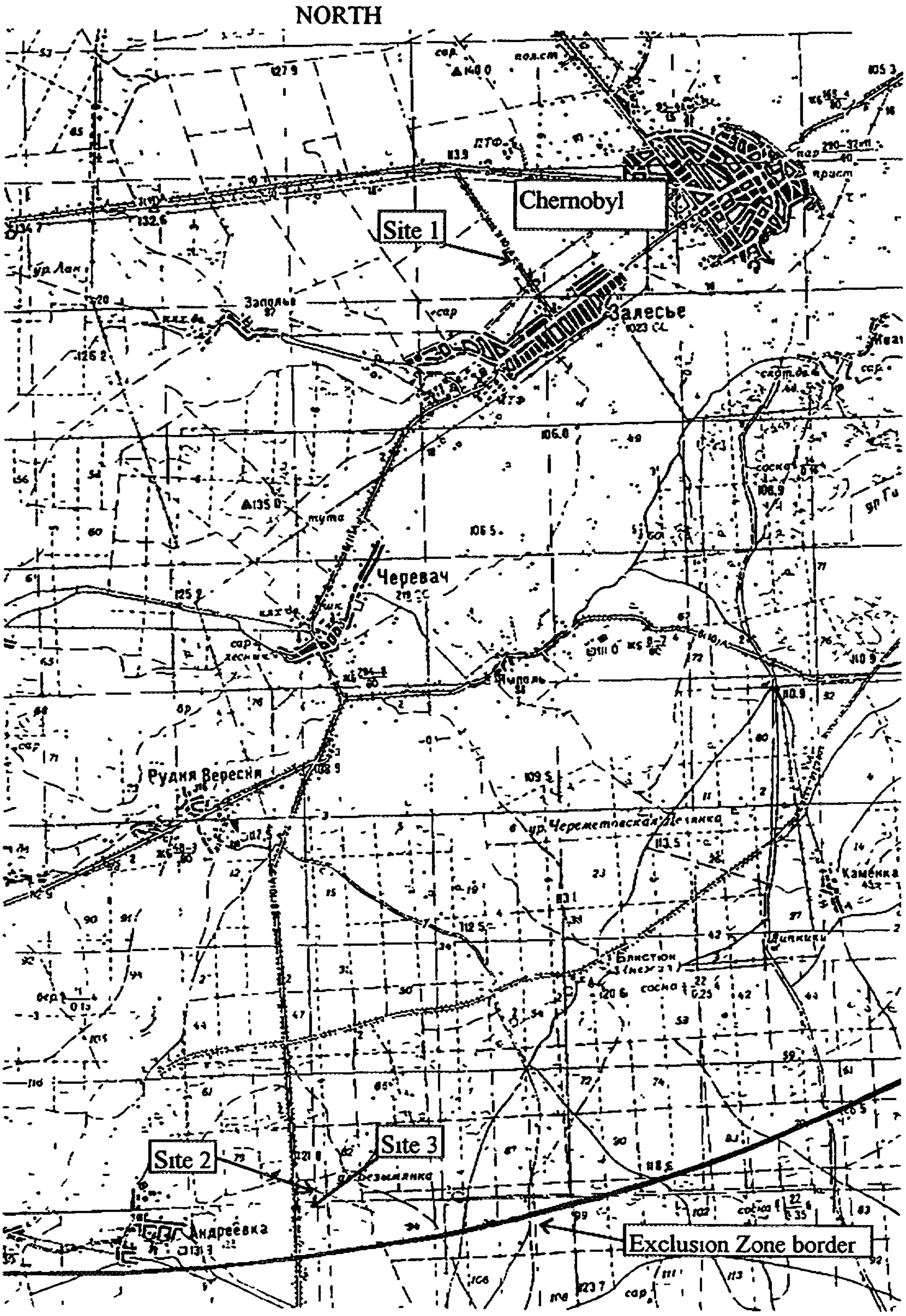


Fig 1 Sites location within the Exclusion Zone

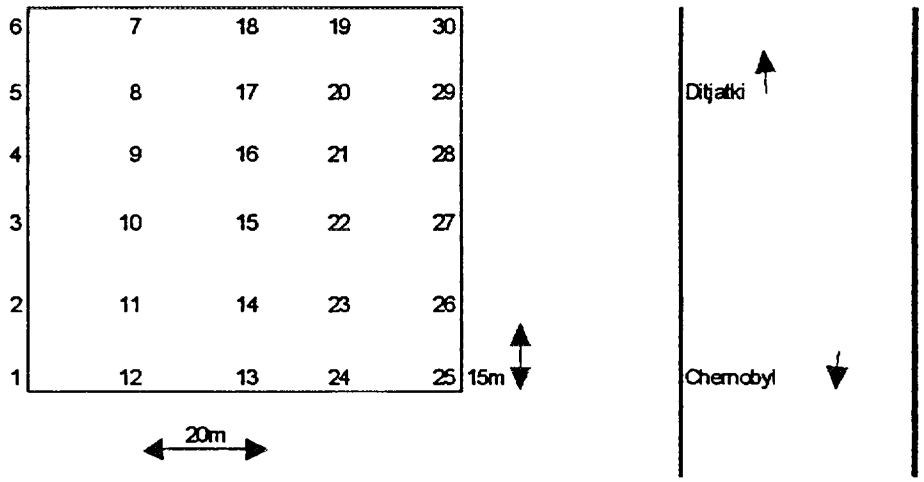
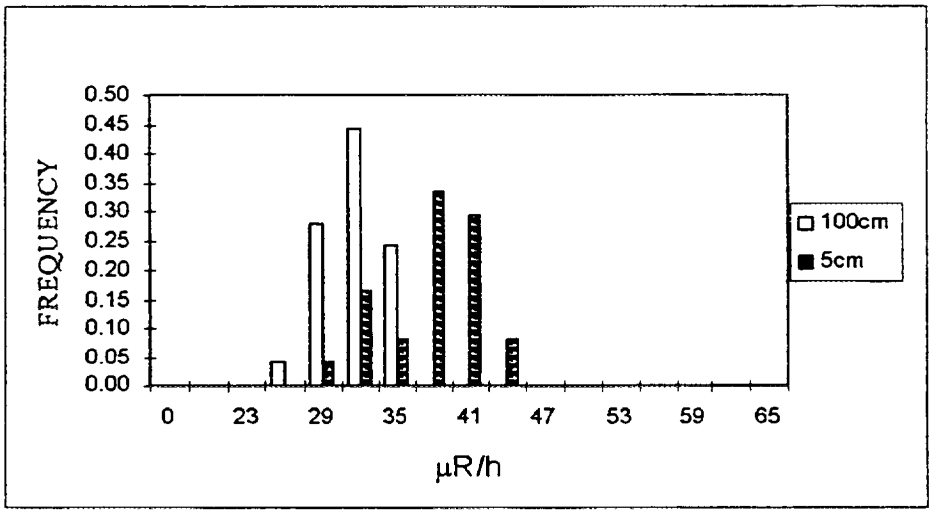
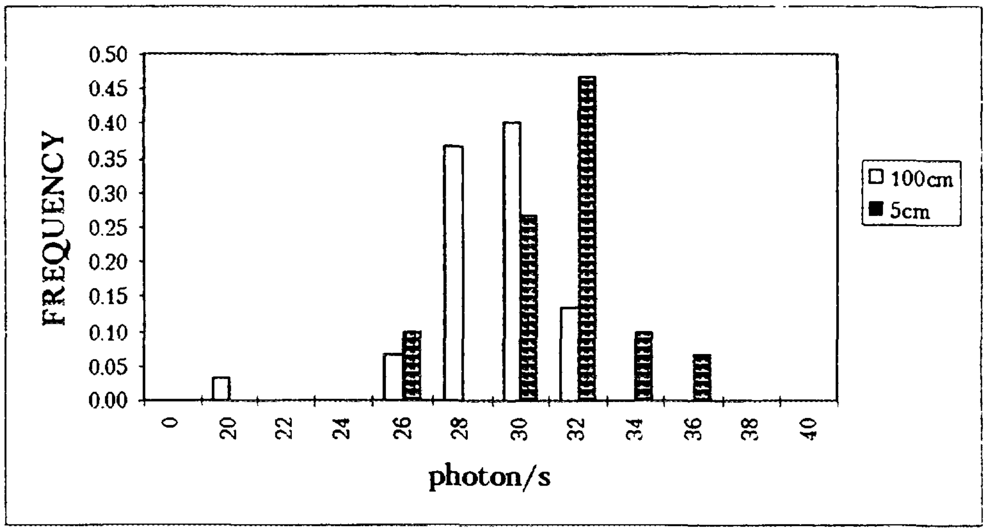


Fig 2. Measurement net for investigated site 2.



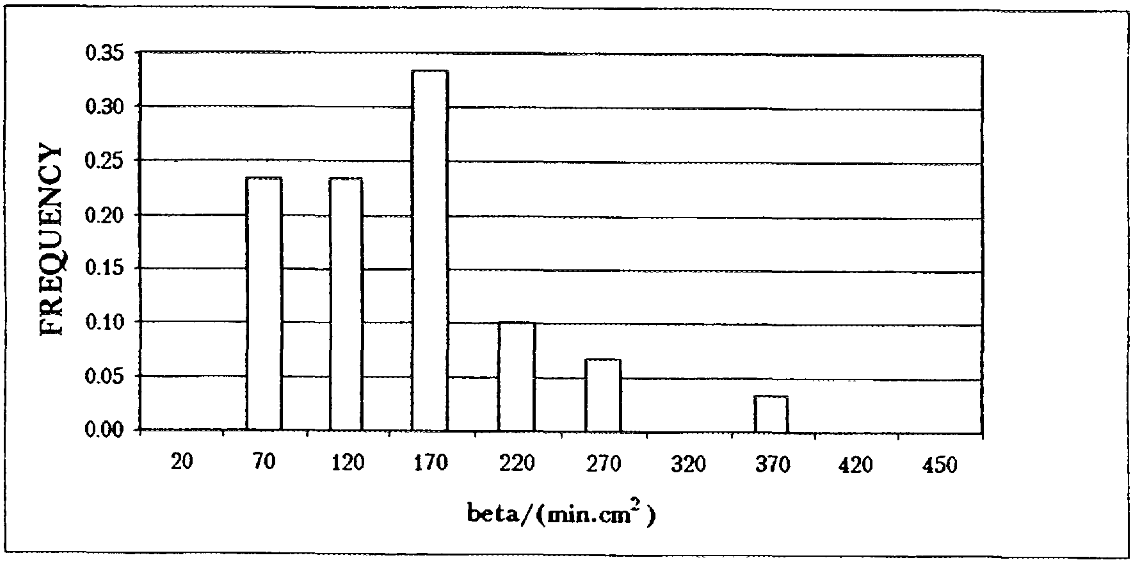
average 1m	33.26
weighted error	3.05
standard deviation	2.36
Total error	3.86
average 0.05m	40.94
weighted error	2.19
standard deviation	4.05
Total error	4.60

FIG.3. Statistical treatment of dose rate results.



average 1m	30.82
weighted error	1.15
standard deviation	1.76
Total error	2.11
average 0.05m	33.54
weighted error	0.94
standard deviation	2.33
Total error	2.51

FIG.3A. Statistical treatment of gamma flux results.



Average	132.83
standard deviation	69.79

FIG.4. Statistical treatment of beta surface results of 30 points.

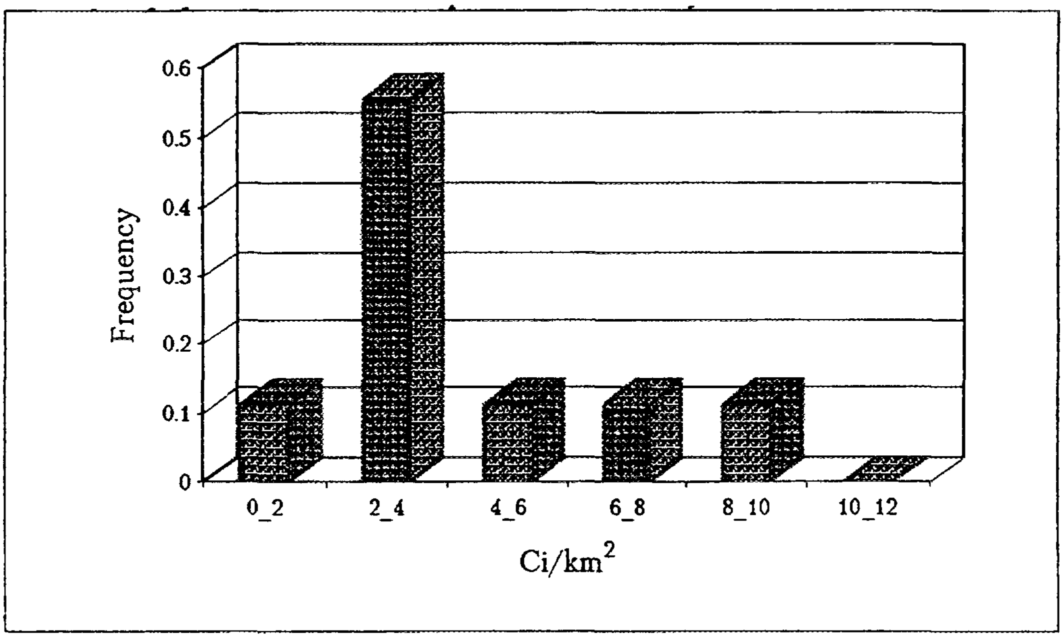


FIG.5. Statistical treatment of the Surface contamination density (sampling)

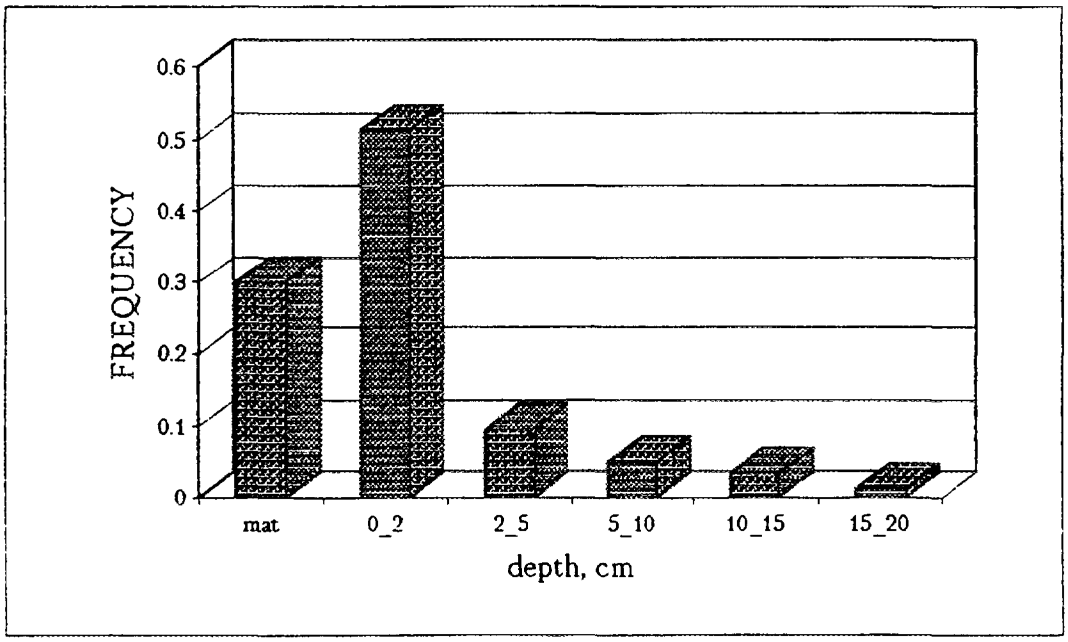


FIG.6. Depth activity distribution for forest site.

Grass and mat sampling

For a site 1 according to [3] grass were collected 1cm above the mat region (2cm above the surface). Only part of grass was collected, which was separated from the underlying mat since radionuclide concentration in the mat were expected to be far greater than that in the grass. For a site 2 a mat was collected from the area 0.25 m^2 and care was taken to avoid collecting the underlying soil material.

In both cases the size of the area sampled and heights of grass were recorded. All samples were packed into plastic bags.

Sample preparation

At the laboratory soil samples were allowed to dry at room temperature for couple days. Then low - temperature (50 ^{0}C) drying continued for about 16 hours. Then dry mass of the whole sample material was recorded. Afterwards samples were crushed, ground with special mill, homogenised and sieved using mesh size 1mm. About half of all samples prepared were tested for homogeneity: each sample was divided into 8 or 10 subsamples and gross - beta counting was measured. The differences never exceed 10-15%.

A prepared sample (120cm^3) was packed into a plastic container and consolidated by shaking. Typical masses were about 140-160 grams.

Gamma - spectrometry measurement

Gamma - emitting radionuclides were determined for all samples by gamma - spectrometer, consisting of 12% Ge(Li) detector, passive steel - lead shielding (mass 4000kg), associated electronics, PC with own - created software for gamma spectra processing [4].

The detector was calibrated with appropriate standard sources. The QC/QA program included every week efficiency and FWHM measurements for point sources ^{137}Cs and ^{60}Co. Also the IAEA references samples [5] were used to control procedures of activity determinations.

RESULTS AND DISCUSSION

Dose rate measurements are presented in Fig. 3, gamma flux measurements in Fig.3A., beta surface contamination in Fig. 4. for both sites. Keeping in the mind results on frequency distribution of above mentioned characteristic it is easy to prove the trueness that the distribution of activity at site 1 is quite uniform from the point of view of dose rate and gamma flux measurements. The only exclusion was observed in point 2, where a hot spot test value [6] gave a value 1.52.

Having calculated uncertainties of Hot Spot Test it should be mentioned, that majority of results is not distinguished, for instance, points 2,3,6,7,8 have approximately the same results. But, at the same time, three different kinds of measurement proved the presence of Hot spot edge at site 1. Concerning the beta measurements at this site, we can see bigger deviations from point to point, but Hot Spot area was detected certainly. The same results were observed for a site 2: big deviations in beta - contamination, but hot spot area was not detected. Also we strove to make fitting of frequency histograms in order to obtain parameters of log-normal or normal distribution. But due to lack of results it was impossible to prove usage of one of different kinds of distribution.

Distribution in the soil profile is presented in Fig. 5 and Table II for site 2.

Table I. Total Surface Contamination Density

Point №	Ci/(Km^2) Activity	error
8	1.960	0.137
9	6.369	0.369
10	2.322	0.125
14	2.987	0.157
15	3.049	0.180
16	2.716	0.155
21	2.255	0.121
22	1.149	0.069
23	5.782	0.347
average		3.180
weighted error		0.18
standard deviation		1.75
Total error		1.756

Table II. Activity of soil profiles.

	Surface contamination density, Ci/km2							
layer	mat	0_2	2_5	5_10	10_15	15_20	total	error
point								
8	0.895	1.814	0.070	0.047	0.022	0.007	2.855	0.137
9	2.336	4.765	0.677	0.461	0.448	0.018	8.705	0.369
10	1.534	1.469	0.195	0.165	0.356	0.137	3.856	0.125
14	0.974	1.644	1.241	0.023	0.043	0.036	3.961	0.157
15	2.048	2.285	0.265	0.373	0.087	0.040	5.097	0.180
16	1.184	1.979	0.218	0.336	0.132	0.051	3.900	0.155
21	1.035	1.391	0.481	0.294	0.069	0.020	3.291	0.121
22	0.744	0.838	0.115	0.099	0.042	0.054	1.893	0.069
23	1.523	4.776	0.571	0.259	0.098	0.078	7.305	0.347
average	1.36	2.32	0.42	0.22	0.14	0.049	4.54	
Weighted error							0.20	
stdev	0.51	1.35	0.34	0.14	0.14	0.037	2.05	
Total error							2.25	

From these tables and figures we can see, that approximately 90-95% of total caesium activity are concentrated in 0-5cm upper layer of soil for a site 1. This result is in a good agreement with other researchers [7].

For a site 2 we found, that approximately 30% of total activity contain in mat and this value twice less than in [8]. But, at the same time, mat and 0-5cm soil layer contain 90-95% of total activity, that is in a good accordance with the same reference.

IN-SITU

In Situ measurements for field and forest sites.

It is wellknown [9], that the fundamental quantities used for *in situ* spectrometry include full absorption peak count rate N, and source activity A. In practice we would like to deal with single factor to convert from the registered full energy absorption peak count rate in the pulse height distribution of a field measurement to the activity concentration (or exposure rate) of gamma-emitting radionuclides surrounded the detector at the investigated site.

The converted formula can generally be written as:

$$A=k_A N_F \qquad (1)$$

where

A - soil radioactivity concentration (Ci/km^2);

N_F - count rate in a representative full energy peak originated from the gamma-emitting nuclide of interest in a field measurements;

k - In situ calibration factor.

Should be noted that the In Situ calibration factor value depends on the in-depth activity distribution profile and absorption properties of the investigated surface (soil for field and soil and forest mat for forest, in our case). Briefly speaking, natural radionuclides are usually uniformly distributed whereas fresh fallout radionuclides cause a surface distribution. In field measurements an unshielded detector simultaneously measures gamma-fields from radionuclides of all types of distribution. But the field area from which principal photons contribute is considerably larger for plane distribution than for uniform distributions. For example that in field measurement of superficially distributed ^{137}Cs at 662 keV 90% of the primary gamma flux originates from distance within 60m (corresponding to a surface area of 11300 m^2). This distance decreases to 8m (corresponding to an area of 200m^2 if the activity is uniformly distributed in the soil. Also, must be noted for distributions that are close to a uniform one, over 90% of the total flux comes from the first 10 cm of soil. The situation is even more extreme in case of a shallow distribution For example, in case of soil density equal cm^2/g, more than 75% of the total flux comes from the first 1mm of soil. It is particularly important to consider this effect when calibration procedures for in situ measurements are carried out.

Due to differenses in radionuclides migration processes and site conditions for fields and forests we compared the results of the In Situ measurements from the calibration factors obtaining points of view.

In Table III the results of In situ and gamma-spectrometric measurements are presented both for field and forest sites.

Table III. In-sity measurement calibration factor for forest and field conditions.

	A, Ci/km^2	Error	Count rate, s^{-1}	Error	k	Error
Field	9.29	40%	572	0.5%	16.2	42%
Forest	4.54	35%	358	0.9%	12.6	37%

CONCLUSIONS

The main results of this article is a group made measurements on environmental monitoring. We can conclude, that:

a). The non-uniformity of caesium activity has to be discussed as the main source of uncertainty, affecting the final results of field exercises. This conclusion is very important for a strategy of survey.

b). To retrieve the true situation of activity distribution as many results as possible should be taken into account.

c). Keeping in the mind about the teaching character of Summer School and presence of team, it should be mentioned, that there is no certain procedure to make measurements in point surrounded by people occasionally. That can be a reason of big standard deviation for dose rate and gamma flux measurement. In the case of beta flux measurement big standard deviation can be explained by different composition of upper layer (soil + mat), overscattering of beta particles, natural transfer (wind, rain, etc.).

d). To obtain statistically meaningful results it is very important to adopt the sampling methodology to real situation of spot - profile radioactive contamination (sampling site, representativity, etc.).

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XA9745847

RADIOLOGICAL EVALUATION OF AN AGRICULTURAL FIELD IN THE CHERNOBYL ACCIDENT AREA

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INTRODUCTION

The vicinity of the Chernobyl Nuclear Power Plant, where happened the most serious nuclear accident seen by mankind a decade ago, renders the opportunity to carry out concrete scientific researches about post conditions of a nuclear accident.

To evaluate the radiological situation of a field formally used for agriculture, inside the Exclusion Zone (30 Km zone around Chernobyl Nuclear Power Plant) a field exercise was organised by the Ukrainian Radiation Training Centre.

To develop a radiological evaluation of a field it is necessary taking into consideration the nature of the sampling site and what are the tasks to be worked out to accomplish the aims of the evaluation. In a case of evaluation of external dose, measurements of dose rate, gamma flux and beta surface contamination are the principal surveys.

The present radioactive contamination in the Exclusion Zone is mostly determined by ^{137}Cs, ^{90}Sr and transuranium radionuclides [1]. Should be noted that on the contaminated area, ten years passing after Chernobyl accident, the dose-rate is formed by ^{137}Cs contamination and beta flux is due to ^{137}Cs + ^{90}Sr. In this report the techniques of measurement dose rate, beta flux and density of contamination of ^{137}Cs have been discussed .

MATERIAL AND METHODS

Description of Site

The field site is a large, open, flat, relatively even and grassy terrain of nondisturbed by any human activity since the accident clay soil. Fig.1 shows the location of the site inside the Exclusion Zone.

Measurements Techniques - Sample Collection and Analysis.

Within a selected area of 10 by 10 meters dose rate and gamma flux were measured for 9 points at two different heights - 0.05m and 1m (Fig.2). Ten measurements for dose rate and for gamma flux were done at each of the points and ten measurements only for dose rate were done around the centre of the selected area. The measurements were performed by a GM tube dose rate meter which an acceptable main error limit (95% confidence interval) of $\pm(30+1.0\text{x[Unit]}/R)\%$, ($R$-dose rate in units of the corresponding subrange -mR/h or R/h) and a scintillation detector with a range from 0 to 10000 s^{-1} for dose rate and gamma flux respectively. The frequency histograms of the results are presented in Fig.3A,3B.

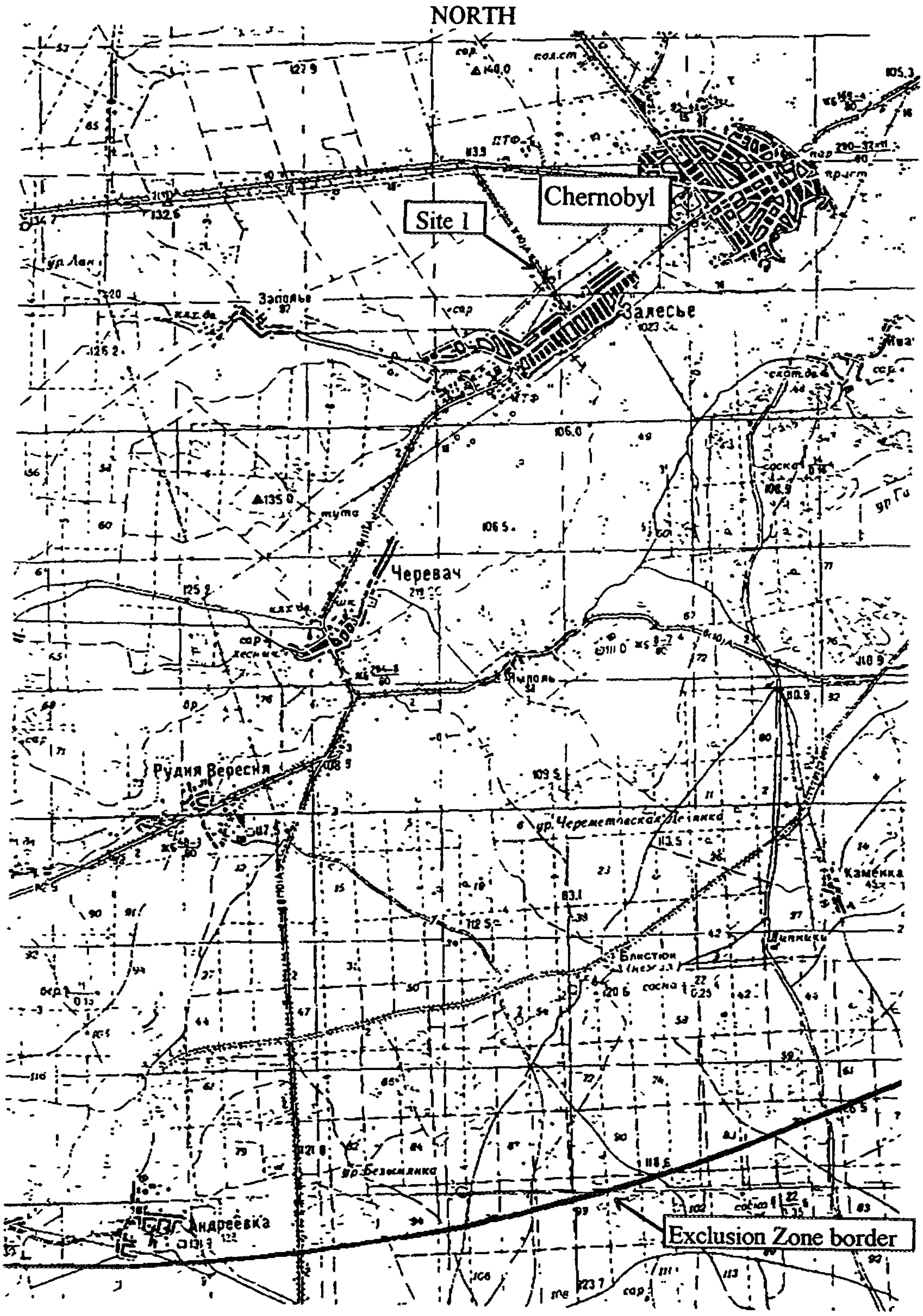

Fig. 1. Site location within the Exclusion Zone.

To determine the beta surface contamination in the selected area, 10 beta/photon flux measurements has been carried out using a beta radiometer with and without a steel screen for 6 points in the area (Fig 2). The difference between the two measurements for a particular point is assumed as the beta flux from the surface contamination taking into account the gamma flux contribution The frequency histogram of the beta surface contamination values is shown on Fig 4

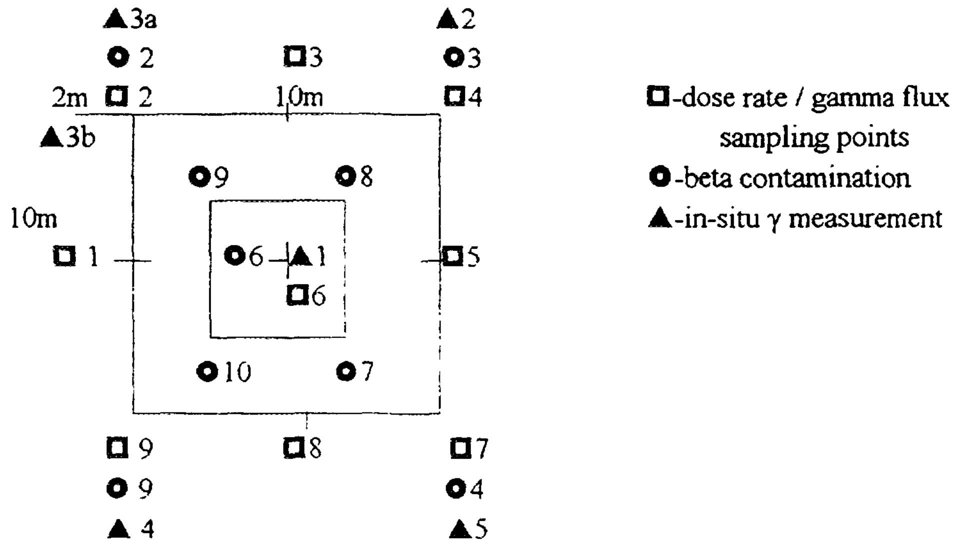

FIG.2. Sketch of measures and sampling at area of 10x10m.

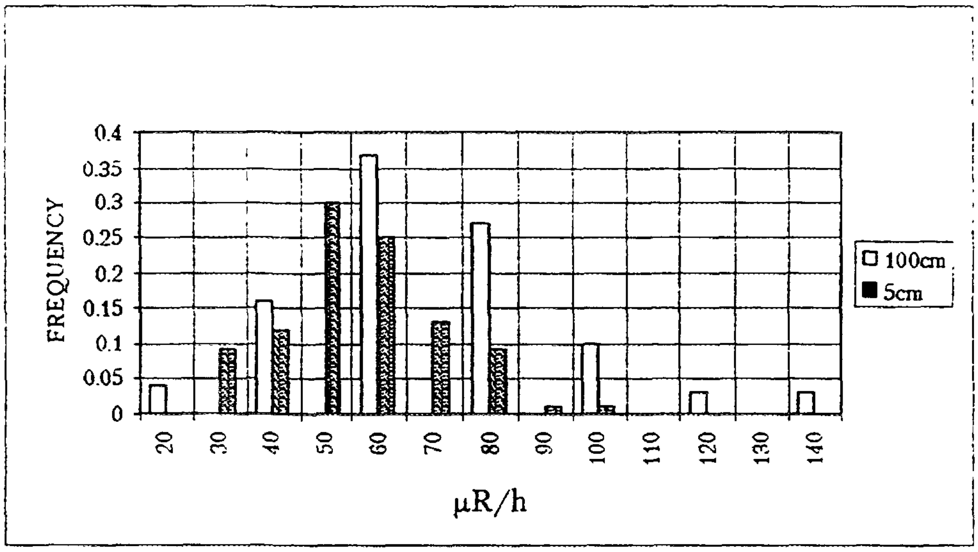

FIG.3A. Statistical treatment of dose rate results.

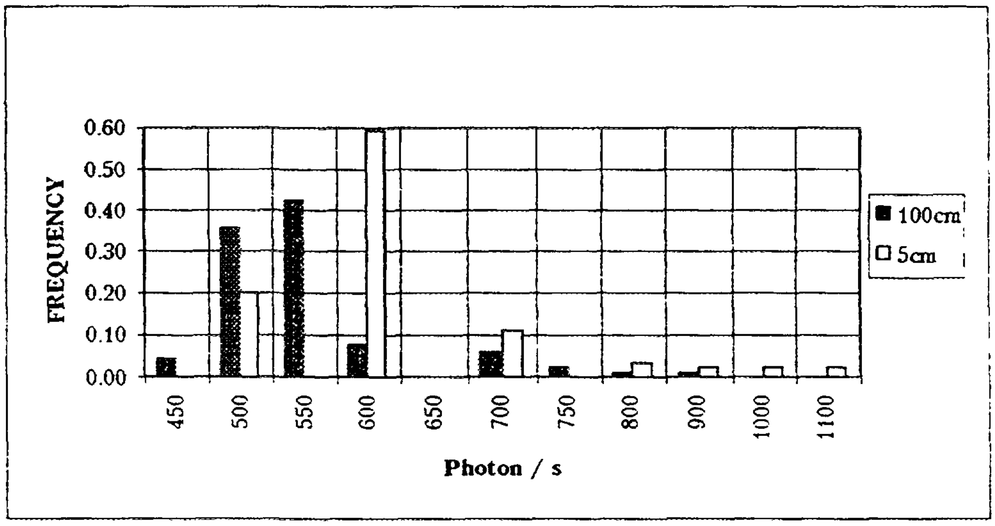

FIG.3B. Statistical treatment of gamma flux results.

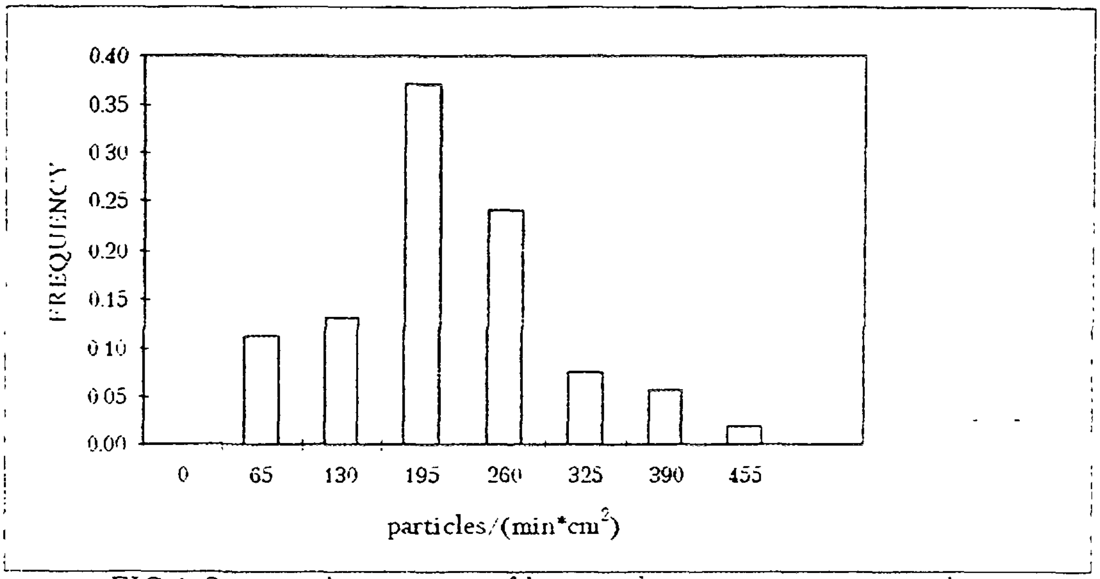

FIG.4. Statistical treatment of beta surface contamination results.

As well known, in practice, the inventory (activity per unity area) of ^{137}Cs through the activity measurement of the collected at the investigated site soil samples or, in case of undisturbed after fallout ground, through the combination of the in-situ measurements and soil sampling.

The best way for obtaining of the more detail information concerning to the contamination of a site should involve in-situ gamma spectra measurements in conjunction with soil sampling method. It can reduces

the number of samples to be collected and gives a representative average activit value for a large area of ground [2]. In-situ gamma measurements were done around and within the investigated area at 5 points for heights of 1m and 0.8m using the Silena Nuclear Processor - SNIP 201N/W and NaI(Tl) detector (Fig.2). The gamma spectra obtained had a post-treatment using the Silena Simcas (Computer-based Nuclear Analysis System) in order for revising in-situ obtained. Fig.5 presented an example of the in-situ gamma spectra obtained.

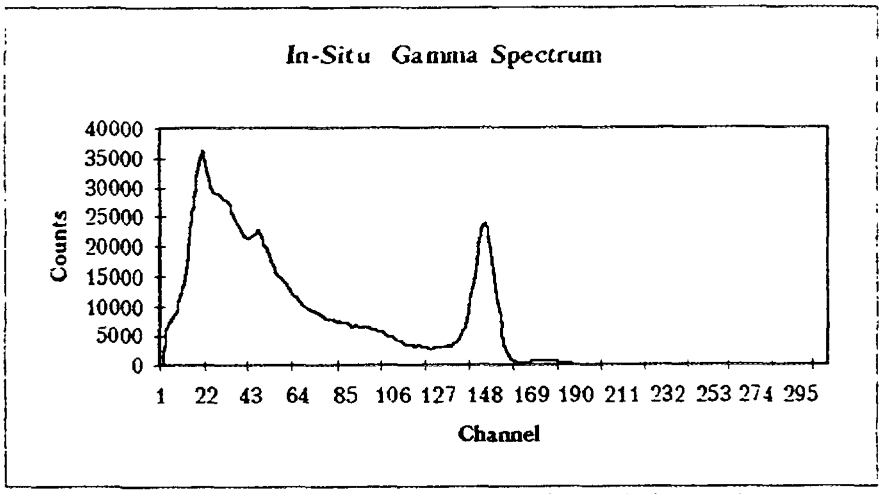

FIG.5. In-situ gamma spectrum (point 2 , height 1m).

Soil samples were taking layer by layer for depth of 0-2 cm; 2-5 cm; 5-10 cm; 10-15 cm and 15-20 cm at 9 selected points (Fig.2) tested for hot spots [3]. A cylindrical metal corer with diameters of 6.0 cm and depth of 20 cm were used for soil sampling in the mentioned points. The cylinder was pushed into the soil by means of a hammer and the soil was pushed out of the cylinder according the core. The corers were used to collect the soil on the desired depth segments with the necessary quantity to performer the preparation procedures of samples for gamma spectra measurements The sectioned samples were sealed in individual plastic bags to subsequent analysis

In order to avoid cross contamination the samples were prepared for gamma measurement beginning from the bottom to the top layer [4]. Then soil samples were dried at low temperature 50^0C for about 16 hours. The dry mass of the total sample was recorded, then the samples were crushed, ground with special mills and sieved using mesh of 1 mm size After sieving the soil samples were weighed and packed into plastic containers for gamma spectrometry [5] Some soil samples were tested for homogeneity in terms of activity.

The gamma spectrometry measurements of the soil samples were done using a semiconductor detector Ge(Li) calibrated with appropriate mixed standards sources [5] The gamma spectra obtained

$$A\left[{}^{Bq}\!/_{kg}\right]=\frac{R_T-R_B}{P_\gamma m\varepsilon},$$

where

R_T is the sample gross count rate ;

R_B is the background count rate ;

ε is the counting efficiency of the specific nuclide's energy ;

P_γ is the absolute transition probability by gamma decay through the selected energy as for ε ;

m is the mass of the sample.

RESULTS

Dose rate, gamma flux and beta surface contamination measurements results and its statistical treatment are presented in Tables I-III respectively. These results show that mentioned above measurements should be used for preliminary assessment of the radioecological condition at the investigated site and can specify more suitable for detail studying points within the given site. Also this measurements can give the original data for evaluation of the external exposure levels [7].

The activities of ^{137}Cs found in the soil samples are presented in Table IV. The error associated with gamma -spectrometry measurements of ^{137}Cs did not exceed 10%.

The results gamma spectra measurements of the soil samples were evaluated statistically. The activity values of the samples from point 2 is in a good agreement with its preliminary hot spot test (dose rate values ratio for both heights = 1.5). Therefore the calculation of the total surface density

The results gamma spectra measurements of the soil samples were evaluated statistically The activity values of the samples from point 2 is in a good agreement with its preliminary hot spot test (dose rate values ratio for both heights = 1.5). Therefore the calculation of the total surface density contamination for the field site should exclude the point 2 values from the consideration The analysed results of the total density of contamination are presented on Table V and the histogram of the statistical treatment in Fig 6

The depth distribution of the specific activity of ^{137}Cs for the field site is presented in Fig 7 The distribution at a depth h in the soil can be fitted by the exponential dependence [8]·

$$A = A_0 \ exp\ [\ -\alpha h\ ]$$

where

- A is the cumulative inventory of ^{137}Cs down to depth h in $Ci\ km^{-2}$
- A_0 is the total inventory of the surface layer in $Ci\ km^{-2}$,
- α is the reciprocal of the relaxation length in cm^{-1}.
- h is the linear depth in cm

Table I. Dose Rate Measurements.

Measurement Point	Height m	Dose Rate (μR/h) Average	Dose Rate (μR/h) Deviation	Hot Spot test
1	1	44 2	11 68	1 16
	0 05	51 3	22 34	
2	1	70 8	6 29	1 52
	0 05	107 5	15 52	
3	1	51 3	5 64	1 33
	0 05	68 2	5 20	
4	1	49 7	3 71	1 04
	0 05	51 8	6 32	
5	1	50 8	6 91	1 18
	0 05	60	18 26	
6	1	49	16 63	1 27
	0 05	62	14 76	
7	1	53	18 89	1 17
	0 05	62	13 17	
8	1	41	17 29	1 12
	0 05	46	20 11	
9	1	51	17 29	1 10
	0 05	56	20 11	
10	1	63	16 36	1 06
	0 05	67	17 03	

average 1m	54 4
weighted error	8 76
standard deviation	8 65
Total error	12 3
average 0 05m	66 8
weighted error	12 2
standard deviation	17 1
Total error	21

TABLE II. Gamma Flux Measurements.

Measurement Point №	Height m	photons/s Average	photons/s Deviation
1	1	496	31 34
	0 05	494	17 13
2	1	707	65 67
	0 05	877 1	144 00
3	1	520	21 08
	0 05	613	25 41
4	1	494	20 11
	0 05	522	27 00
5	1	536	16 47
	0 05	533	17 03
6	1	526	32 39
	0 05	559	18 53
7	1	494	22 71
	0 05	559	18 53
8	1	473	24 06
	0 05	490	23 57
9	1	526	20 66
	0 05	568	22 01

average 1m	518 17
weighted error	22 64
standard deviation	69 37
Total error	72 97
average 0 05m	546 07
weighted error	20 92
standard deviation	118 03
Total error	119 87

Table III. Beta Surface Contamination.					
		Particles /(min.cm^2)			
Point	screen	Average	Deviation	Beta flux	Deviation
1	yes	55.33	3.98	141.34	57.64
	no	196.67	57.5		
2	yes	150.67	2.16	342.66	56.49
	no	493.33	56.45		
3	yes	54	6.03	181.33	18.95
	no	235.33	17.96		
4	yes	52.5	4.23	204.17	62.96
	no	256.67	62.82		
5	yes	49.33	2.58	45.67	14.02
	no	95	13.78		
6	yes	54.83	2.79	160.84	22.75
	no	215	22.58		
7	yes	54.16	5.04	240.84	23.14
	no	295	22.58		
8	yes	51.83	5.27	201.5	23.12
	no	253.33	22.51		
9	yes	54.33	6.06	113.5	31.00
	no	167.83	30.4		
		average		198.13	
		weighted error		29.97	
		standard deviation		83.31	
		Total error		88.53	

Table IV. Activity of Cs-137 in soil profiles (Ci.km^{-2})

Point	Layer									
	Cs-137 (value and error)									
№	0-2cm		2-5cm		5-10cm		10-15cm		15-20cm	
1	4.258	0.328	3.443	0.255	0.597	0.045	0.686	0.049	0.023	0.002
2	17.368	1.244	9.263	0.671	2.116	0.162	0.337	0.026	n.a	
3	5.304	0.382	3.700	0.280	0.500	0.010	0.026	0.002	0.019	0.004
4	7.188	0.537	1.089	0.090	0.480	0.037	0.127	0.011	0.031	0.007
5	4.434	0.338	3.759	0.270	0.365	0.027	0.126	0.017	0.055	0.012
6	4.511	0.326	1.404	0.107	0.251	0.020	0.105	0.009	0.021	0.006
7	6.071	0.458	2.349	0.175	0.391	0.028	0.103	0.009	0.035	0.009
8	7.987	0.575	3.590	0.265	0.274	0.022	0.100	0.010	0.065	0.005
9	7.982	0.580	2.735	0.201	0.217	0.015	0.089	0.010	0.055	0.004
average*	5.97		2.81		0.46		0.218		0.048	
weighted error*	0.44		0.21		0.016		0.017		0.005	
standard deviation*	1.58		1.06		0.134		0.211		0.018	
Total error *	1.64		1.08		0.135		0.211		0.019	

n.a. -not avaliable

*.without values point 2

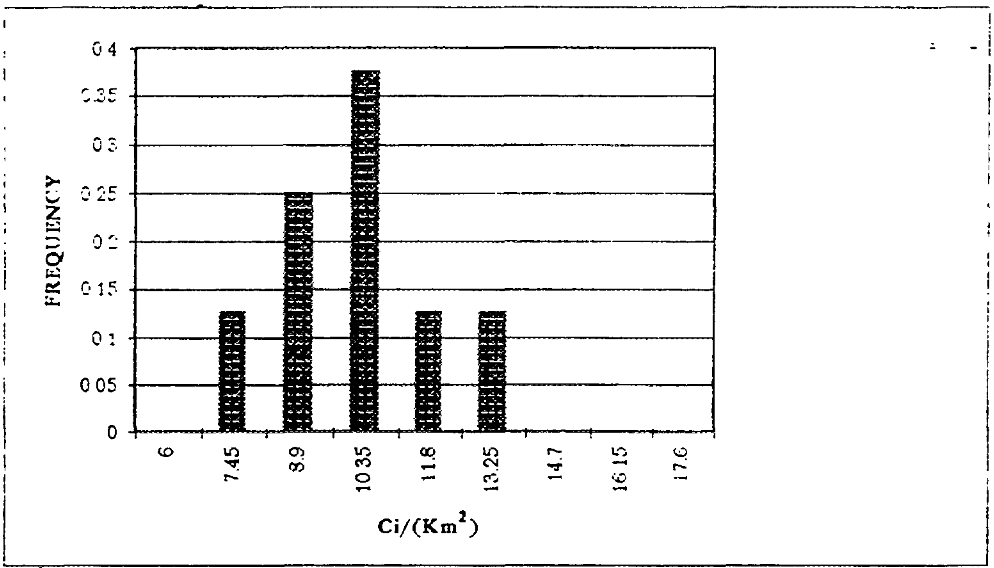

FIG.6. Statistical treatment from the results for total contamination density of soil samples gamma spectra measurements.

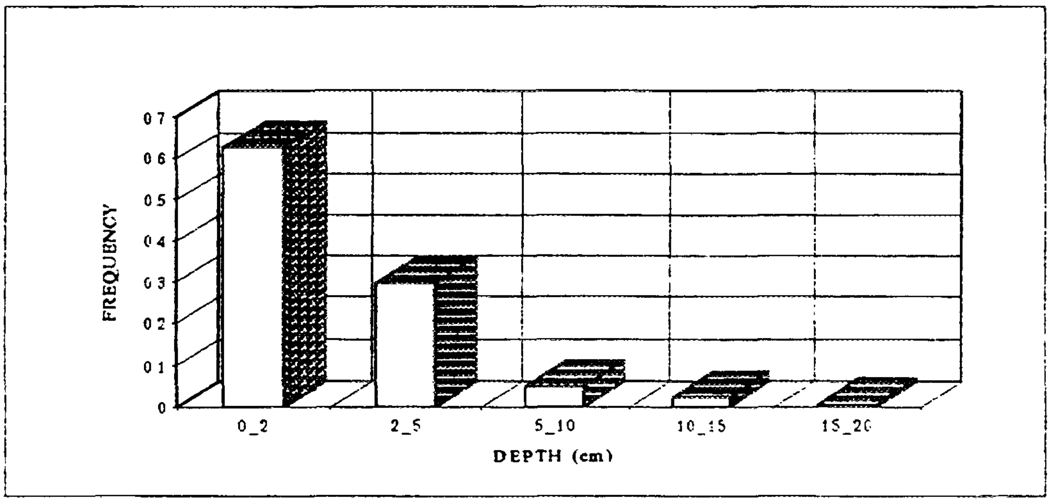

Fig 7. The depth activity distribution for soil profiles.

TABLE V. Total Surface Contamination Density. -2

Point №	Activity	error
1	9.01	0.42
3	9.52	0.47
4	8.88	0.55
5	8.71	0.43
6	6.27	0.34
7	8.91	0.49
8	11.97	0.63
9	11.03	0.61
average	9.29	
weighted error	0.49	
stantard deviation	1.69	
Total error	1.76	

The two top layers of the field site contains ~ 94 % of ^{137}Cs of the total activity showing that this radionuclide still remains at the superficial layers on a fixed form ten years after the Chernobyl accident.

The in-situ gamma spectral results are presented in Table VI. The results of ^{137}Cs surface density contamination obtained by soil sampling method and in situ measurements can be used for in-situ calibration factor k obtaining by means relation:

$$A[Ci\ km^{-2}] = k\ cps[s^{-1}]$$

where :

$$k = \frac{A[Ci\ km^{-2}](Soil\ sampling)}{cps[s^{-1}](In\text{-}Situ\ measurement)}$$

Table VI. In-Situ Gamma Spectral Measurement

Point №	Height m	Cs -137 cps	error %
1	1	512.98	0.57
	1	511.27	0.57
	0.8	514.42	0.57
2	1	503.81	0.57
	0.8	541.76	0.55
3A	1	807.69	0.45
	0.8	850.36	0.44
3B	0.8	694.03	0.48
4	1	429.74	0.63
	0.8	456.79	0.61
5	1	498.83	0.58
	0.8	520.37	0.57
average 1m		572.48	
weighted error		3.06	
standard deviation		132.87	
Total error		132.91	
average 0.8m		628.42	
weighted error		3.20	
standard deviation		147.65	
Total error		147.69	

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THEORETICAL SURVEY OF EXPERIMENTAL RESEARCH INTO RADIONUCLIDE MIGRATION IN SOILS IN THE ACCIDENT ZONE WITH A VIEW TO PREDICTING AND CONTROLLING THE PROCESS

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ТЕОРЕТИЧЕСКОЕ ОБОБЩЕНИЕ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ МИГРАЦИИ РАДИОНУКЛИДОВ В ГРУНТАХ ЗОНЫ АВАРИИ С ЦЕЛЬЮ ПРОГНОЗИРОВАНИЯ И РЕГУЛИРОВАНИЯ ПРОЦЕССА

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The investigation analysis carried out at stationary observation point nets on the radionuclide migration ability shows that the process of radionuclide lateral migration decays. At present the vertical radionuclide migration has predominant importance. In this connection we have formulated and solved the general dynamic problem of sorption from multicomponent solution.

It was determined the following:

-the function of the completeness of the process for sorption into the spherical particle from constantly renewed solution and general expression for output curve for linear isotherm;

- on the base of expression for output curve at the linear isotherms - the possibility to realise the mode for movement rate of the front with constant radionuclide concentration and the characteristics of this mode allowing to solve practical tasks for the regulation of radionuclide migration rate;

- the definition of the protective action of soil layer in the connection with the main parameters of the sorption process.

The materials obtained can be used for prediction of radionuclide migration in various soils and preventing radionuclide contamination in pure soils and territories.

Анализ исследований, проведенный на сети стационарных наблюдательных пунктов, по миграционной способности радионуклидов, показывает, что процесс их латеральной миграции затухает. В настоящее время преобладающее значение имеет вертикальная миграция. В этой связи нами сформулирована и решена общая динамическая задача сорбции из многокомпонентного раствора при линейной изотерме. На основании этих решений предложена методика прогноза миграции радионуклидов в грунтах зоны аварии и разработаны рекомендации для проведения работ с целью регулирования этого процесса.

1. ОБЩАЯ ПОСТАНОВКА ЗАДАЧИ

Суть общей постановки задачи состоит в том, что для математического описания процесса многокомпонентной динамики сорбции необходимо решить совместную систему уравнений [1, 2] , состоящую из кинетического уравнения (1) и уравнения материального баланса (2):

$$a_i(x,t)=\frac{1}{V}\int_V \bar{C}_i(r,x,t)d\vec{r}=\frac{1}{V}\int_V\left\{K_iC_i(r,x,t)+\sum_{j=1}^{n}K_{ij}C_i(r,x,t)C_j(r,x,t)\right\}d\vec{r} \qquad (1)$$

$$\alpha\frac{\partial C_i(x,t)}{\partial t}+(1-\alpha)\frac{\partial a_i(x,t)}{\partial t}+\upsilon\frac{\partial C_i(x,t)}{\partial x}=D_i\frac{\partial^2 C_i(x,t)}{\partial^2 x}+f_i(x,t),\quad i=1,...,n \qquad (2)$$

Уравнение (1) описывает взаимосвязь усредненной концентрации каждой из компонент раствора в сферической частице грунта $a_i(x,t)$ в момент времени t в сечении грунта, находящемся на расстоянии x от начала. В уравнениях (1) и (2) $\bar{C}_i(r,x,t)$, $C_i(x,r,t)$ - концентрации i-той компоненты раствора в слое сферической частицы радиусом r и толщиной δr и в объеме раствора соответственно в момент времени t в сечении грунта x; υ - линейная скорость раствора в грунте; α-порозность слоя грунта; n - число компонент раствора; V - объем поглощающего слоя грунта.

В правой части уравнения материального баланса (2) первое слагаемое описывает перенос РН за счет молекулярной диффузии (D_i - коэффициент молекулярной диффузии i-го РН), второе слагаемое $f_i(x,t)=R_i\prod_{j=1}^{n}C_j^{V_{ij}}$ определяет связывание i-го РН в процессе необратимой химической реакции R_i - константа скорости химической реакции, V_{ij} - стехиометрические коэффициенты.

В уравнении (1) использовано выражение для i -той компоненты раствора в виде:

$$\bar{C}_i=K_iC_i+\sum_{j=1}^{n}K_{ij}C_iC_j,\qquad K_i,K_{ij}-const \qquad (3)$$

связывающее концентрации сорбтива внутри сферической частицы грунта с концентрацией вещества в растворе. Предполагается, что частицы грунта в поглощающем слое однородны. В том случае, если K_{ij}=0, уравнения (1), (2) становятся независимыми для каждой из компонент и, следовательно, могут быть решены для каждой из них отдельно.

Концентрация i - той компоненты раствора в сферическом слое частицы радиуса r и толщиной δr $\bar{C}_i(r,x,t)$ в момент времени t и в сечении слоя грунта x и находящейся с ней в равновесии концентрации раствора $C_i(r,x,t)$ (расчетные, но не наблюдаемые величины) должны быть определены на основе решения задачи диффузии этой компоненты в сферическую частицу грунта

$$\bar{D}_i\,\Delta\bar{C}_i(r,x,t)=\frac{\partial\bar{C}_i(r,x,t)}{\partial t} \qquad (4)$$

где Δ - лапласиан в сферических координатах пространства частицы; $\bar{D}_i$ - коэффициент диффузии i- той компоненты в частице грунта. Подставив в (4) выражение (3), получим уравнение для $C_i(r,x,t)$

$$\bar{D}_i\,\Delta C_i(r,x,t)=\frac{\partial C_i(r,x,t)}{\partial t}-f_i(r,x,t), \tag{5}$$

$$f_i(r,x,t)=\frac{\bar{D}_i}{K_i}\sum_{j=1}^{n}\{2K_{ij}\,\vec{\nabla}C_i\,\vec{\nabla}C_j+\frac{K_{ij}(\bar{D}_i-\bar{D}_j)}{\bar{D}_i}C_i\Delta C_j+\frac{K_{ij}C_i}{\bar{D}_i}(\bar{D}_j\,\Delta C_j-\frac{\partial C_j}{\partial t})+$$

$$+\frac{K_{ij}C_i}{\bar{D}_i}(\bar{D}_i\Delta C_i-\frac{\partial C_i}{\partial t})\ \} \tag{6}$$

где $\vec{\nabla}$ - оператор градиента.

Уравнения (1), (2), (5), (6) длжны быть дополнены начальными и граничными условиями

$$C_i(x,0)=0, \qquad 0<x<L; \qquad C_i(0,t)=C_{0i}, \qquad 0<t<\infty \tag{7}$$

где L - длина колонки; C_{0i} - постоянное значение концентрации i - той компоненты у поверхности частицы грунта.

На поверхности частицы принимается условие равенства потоков вне и внутри объема частицы грунта радиуса R

$$\bar{D}_i\frac{\partial\bar{C}_i}{\partial r}=\bar{D}_i\left[K_i\frac{\partial C_i(r,x,t)}{\partial r}+\sum_{j=1}^{n}K_{ij}\frac{\partial C_i(r,x,t)C_j(r,x,t)}{\partial r}\right]=\frac{D_i}{\delta}\left[C_i(x,t)-C_i(r,x,t)\right],$$

$$r=R \tag{8}$$

где D_i - коэффициент диффузии i - той компоненты раствора; δ - толщина пограничного слоя, зависящая от гидродинамических условий на поверхности частицы. В выражении (8), в правой части поток на поверхность сорбента представлен в виде конечной разности концентраций в глубине раствора и у поверхности частиц грунта.

На границе сферического поглощающего слоя частиц толщиной l поток обращается в нуль для каждой из компонент раствора

$$\bar{D}_i\left(K_i\frac{\partial C_i(r,x,t)}{\partial r}+\sum_{j=1}^{n}K_{ij}\frac{\partial C_i(r,x,t)C_j(r,x,t)}{\partial r}\right)=0, \quad r=R-l, \quad 0\le l\le R \tag{9}$$

В начальный момент времени концентрация сорбтива в частице равна нулю

$$C_i(r,x,0)=C_i(r,x,0)=0, \qquad i=1,\ldots,n \tag{10}$$

На этом общую постановку задачи динамики сорбции из многокомпонентного раствора слоем частиц грунта можно считать завершенной.

Определенный нами подход к исследованию миграции РН значительно отличается от обычно используемого и основанного на применении эмпирических соотношений в кинетических уравнениях [3-5]. Основное отличие состоит в определении в нашей постановке микроскопических процессов миграции в поглощающую частичку почвы, справедливых для любых кинетических режимов [1].

2. РЕШЕНИЕ КИНЕТИЧЕСКОЙ И ДИНАМИЧЕСКОЙ ЗАДАЧ МИГРАЦИИ РАДИОНУКЛИДОВ ДЛЯ ЛИНЕЙНОЙ ИЗОТЕРМЫ И ФРОНТАЛЬНОЙ СОРБЦИИ

С учетом опытных данных , упростим задачу миграции РН. Как известно [6], в большинстве исследованных почв в адсорбированном состоянии находится преобладающее количество РН (80-97% ^{90}Sr). Таким образом далее будем учитывать лишь сорбционный механизм поглощения РН (т.е. $f_i(x,t)=0$). Примем также существование линейной изотермы на участке изменения концентрации РН (т.е. $K_{ij}=0$). Сделаем еще одно предположение, сильно упрощающее систему уравнений (1), (2), (5), и полагаем, что сорбция протекает в режиме фильтрования, т.е. число Пекле $Pe=\dfrac{\vartheta h}{D_i}>>1$ (h - интервал существенного изменения концентрации РН по глубине почвы). Обычно это предположение выполняется хорошо (см. ниже).

Система уравнений для каждого из РН (1), (2), (3), (5) (индекс i опускается) преобразуется к виду

$$a(x,t)=\frac{K}{V}\int_V C(r,x,t)d\vec{r}=K\int_0^t F_0(t-t')\frac{\partial C(x,t')}{\partial t'}dt', \qquad (11)$$

$$\alpha\frac{\partial C}{\partial t}+(1-\alpha)\frac{\partial a}{\partial t}+\vartheta\frac{\partial C}{\partial x}=0, \qquad \overline{C}=KC, \qquad (12)$$

$$\overline{D}\Delta C(r,x,t)=\frac{\partial C(r,x,t)}{\partial t}. \qquad (13)$$

В уравнении (11) использовано соотношение Дюамеля [7], определяющее усредненную концентрацию каждого из РН в поглощающей частичке почвы, через функцию степени завершенности процесса заполнения частички

$$F_0(t)=\frac{1}{V}\int_V\frac{C(r,t)}{C_0}d\vec{r}, \qquad (14)$$

где C(r,t) -решение задачи о внутренней диффузии РН в поглощающую частичку, определяемое уравнением (13) при граничных и начальных условиях:

$$\overline{D}\frac{\partial\overline{C}(r,t)}{\partial r}=\overline{D}K\frac{\partial C(r,t)}{\partial r}=\frac{D}{\delta}(C_0-C(r,t)),\qquad r=R, \tag{15}$$

$$\overline{D}\frac{\partial\overline{C}(r,t)}{\partial r}=\overline{D}K\frac{\partial C(r,t)}{\partial r}=0,\qquad r=R-\ell, \tag{16}$$

$$C(r,0)=0. \tag{17}$$

Таким образом, задача о внутренней диффузии в поглощающую частичку почвы может быть решена независимо от задачи миграции РН (уравнение (12)). Для последней задачи начальные и граничные условия имеют вид:

$$C(x,0)=0,\quad 0<x<\infty;\qquad C(0,t)=C_0,\quad 0<t<\infty. \tag{18}$$

Решение общей задачи (11)-(14) при граничных и начальных условиях (15)-(18) произведено в [1]. Воспользуемся этими результатами и, учитывая независимость задачи диффузии РН внутрь поглощающей частички от задачи миграции, приведем выражения для функции завершенности процесса:

$$F_0(\tau)=1-\sum_n B_n\exp(-\mu_n^2\tau), \tag{19}$$

$$F_0(\tau)=\begin{cases}\dfrac{3Bi}{1+\rho+\rho^2}(\tau-\dfrac{4Bi}{3\sqrt{\pi}}r^{3/2}\ldots), & Bi\sqrt{\tau}\ll 1,\quad \sqrt{\tau}\ll 1;\\[2ex] \dfrac{3}{1+\rho+\rho^2}\left[2\sqrt{\dfrac{\tau}{\pi}}-(1-\rho)\tau+\ldots\right], & Bi\sqrt{r}\gg 1,\quad \sqrt{\tau}\ll 1;\end{cases} \tag{20}$$

где $\tau=\frac{Dt}{\ell^2}$ - безразмерное время, $\rho=1-\frac{\ell}{R}$, $Bi=\frac{D\ell}{\overline{D}K\delta}$ - диффузионный критерий Био для сферического поглощающего слоя частицы толщиной l, определяющей соотношение вкладов внешней ($Bi\to 0$) и внутренней ($Bi\to\infty$) диффузии,

$$B_n=\frac{6Bi^2\left[\rho^2\mu_n^2+(1-\rho)^2\right]}{(1+\rho+\rho^2)\mu_n^2D(\mu_n)}, \tag{21}$$

$$D(\mu_n)=\rho^2\mu_n^4+\mu_n^2\left[\rho^2Bi\ (Bi\ +2\rho-1)+(1-\rho^3)(1-\rho)\right]+Bi\ (1-\rho)(Bi\ -1+\rho),$$

μ_n - корень трансцендентного уравнения (не равный нулю)

$$\mu_n ctg\mu_n=1-\frac{Bi\ -\rho\mu_n^2}{\rho Bi\ +(1-\rho)^2}. \tag{22}$$

Выражения (20) определяют функцию завершенности процесса при малых временах ($\tau \to 0$) во внешне ($Bi \to 0$) и внутриенидиффузионной ($Bi \to \infty$) областях.

Решение проблем миграции РН в почвах приведем в предельном случае существования квазистационарной скорости движения фронта постоянной концентрации; образующегося при больших обобщенных длинах поглощающего слоя $\mu_1\sqrt{\frac{B_1\lambda(x)}{3}} >> 1$, $\lambda(x) = \frac{3(1-\alpha)Kx\overline{D}}{\ell^2 \upsilon}$ [1]. Большие $\lambda(x)$ не означают больших значений поглощающего слоя.

Значение стационарной скорости движения фронта постоянной концентрации определяется выражением [1]:

$$\vartheta_{стац} = \frac{4\vartheta}{(4-3B_1)(1-\alpha)K}, \qquad \mu_1\sqrt{\frac{B_1\lambda}{3}} >> 1 \tag{23}$$

Таким образом стационарная скорость движения фронта (23) пропорциональна средней скорости потока почвенной влаги, обратно пропорциональна безразмерному коэффициенту распределения (равному $K=K_d\gamma$, K_d - обычный коэффициент распределения (см^3/г), γ(г/см^3) - (плотность почвенного грунта) и зависит от характера кинетики процесса поглощения РН частичкой почвы (что определяется коэффициентом B_1).

3. ОЦЕНКА ПОТОКА МИГРАЦИИ РАДИОНУКЛИДОВ В ПОЧВЕННОМ СЛОЕ НА ОСНОВЕ МОДЕЛИ ФРОНТАЛЬНОЙ СОРБЦИИ

Основываясь на выражении о квазистационарной скорости движения фронта постоянной концентрации (23), проведем оценку конвективного переноса РН почвенной влагой. Величину среднегодовых потоков почвенной влаги можно считать лежащими в интервале (0.3 - 30) см/год [6]. Для большинства почв коэффициент распределения K_d ^{90}Sr лежит в интервале (0.3 - 30) см^3/г [6]. Выбрав в качестве оценки средние значения этих величин и воспользовавшись формулой (23) получаем для $\upsilon_{стац}$ ~ 2 см/год, т.е. за истекший период после аварии область проникновения РН составляет ~ 20 см. Глубины проникновения РН такого порядка находятся в ландшафтах 30 км зоны ЧАЭС (см., например, [8]). Выполненные выше оценки величины миграции РН показывают важность определения почвенных характеристик (коэффициента распределения K_d и кинетики поглощения РН частицами почвы, коэффициент B_1, в формуле (23), и пористости α для детального определения областей интенсивной миграции.

ВЫВОДЫ:

1. Определены общие уравнения, граничные и начальные условия, описывающие миграцию РН в почвенном слое с учетом разнообразных химических трансформаций (адсорбции, ионном обмене, химических реакциях и т.п.).
2. Приведено решение кинетической задачи миграции РН в поглощающую частицу почвы в общем виде с учетом смешаннодиффузионной кинетики сорбции (формулы (19)-(22)).

3. Решение динамической задачи миграции РН в почве приведено в пределе существования квазистационарного фронта постоянной концентрации (формула (23)) и произведены оценки потоков миграции РН.

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CLINICAL STATE, REPRODUCTIVE AND PRODUCTIVE INDICES OF CATTLE IN THE NEAR ZONE OF THE CHERNOBYL NPP

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Clinical state, reproductive and productive indices of cattle in the closest zone of Chernobyl NPP

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Since 1987 specialists of Scientific and Technical Centre of RIA "Pripyat" carry out investigations of physiological and cytogenetic state of cattle at an experimental vivarium at the 30-km Chernobyl zone. The animals are represented by ones endured the Chernobyl accident at the closest zone and their generation, and by animals carried inside the zone after 1990. The first animals got about 130 Gy on thyroid gland, 2.5 Gy on whole body and 10-11 Gy on gastro-intestinal tract. Some health decline of them were observed in 1987-1988. During last 5 years of the research the most indices of cattle state, as well as productivity and reproduction, are in physiological norm limits. Since 1989 yearly calves of three generation have got from all suffered cows. Decrease of chromosome aberrations frequency to total population level has been showed. Some data testify of tension existence in hemopoietic and antioxidantic systems of organism. Nevertheless, until now there is no unique opinion of origin nature of the found atypical features. In the report numerous data of hematological, biochemical, hormonal, cytogenetic features of the animals have been presented and discussed.

XA9745850

SATELLITE COMMUNICATION SYSTEM FOR EMERGENCY MONITORING WITHIN THE CHERNOBYL EXCLUSION ZONE

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A Satellite Emergency Monitoring system of the Chernobyl Exclusive Zone (SEM CEZ) was designed to provide the Ukraine authorities and the neighbouring countries with updated information when an emergency situation occurs in the Exclusion Zone This is of particular importance when environment contamination has transboundary effect

SEM system consists of mobile and fixed sensors reporting data via a dedicated satellite communications link Mobile sensors are fitted with Global Positionning System (GPS) receivers that determine current coordinates of the sensor

Sensors data are transmitted to the Emergency Monitoring Centre equipped with PC and a satellite terminal. Both sensors data and the current position are visualized on digital maps

Transmission and reception of sensors data and position are performed thanks to the PRODAT-2 system, a store-and-forward satellite communication system promoted by the European Space Agency

In addition to usual features of other satellite messaging systems, PRODAT-2 allows to exchange data messages from mobile terminal to mobile terminal, in total independance of the telephone infrastructure (PSTN) To take advantage of this feature, the fixed user application, the Emergency Monitoring Center, was developed around a mobile terminal installed in a fixed position

PRODAT-2 also allows multi-recepient messages It means that one mobile transmission may be automatically routed towards preset various destinations This allows parallel monitoring of the same emergency situation from any place within the satellite footprint, i e all Europe (West and East)

Field tests in Chernobyl Exclusion Zone started in May 1994. Specific experiments were carried under ESA contract

The High Technology Institute (Kiev) and the Administration of Chernobyl Exclusive Zone in cooperation with FIAR (Italy) and SAIT Systems S.A. (Belgium) led dedicated experiments to assess the efficiency of PRODAT-2 system for radiation monitoring within the Exclusion Zone.

The first trials were carried out with sensors interfaced with PRODAT-2 Mobile Earth Station (MES). Two kinds of mobile were chosen to carry the sensors : ground based vehicle and light aircraft. Two Emergency Monitoring Centers were set up : one in Kiev and another in Brussels

A Radiation Reconnaissance Vehicle, equipped with a radioactivity sensor, was travelling while measuring the local level of radioactivity. A PRODAT-2 MES, connected via serial line to the sensor, was in charge of sending to Kiev and to Brussels at the same time, the sensor data together with the mobile position thanks to an internal GPS receiver (Photo 1) For the time being, data collection at mobile side is based on a User Terminal emulation, that requests a portable PC inserted between MES and sensor To reduce installation cost in the mobile and to favor flexibility, a programmable Intelligent Serial Interface (electronic stand-alone equipement working without human intervention), will interface directly the sensor through the serial port of the PRODAT mobile terminal

When received, sensor data and mobile position are displayed on a digital map, simultaneously in Kiev and in Brussels (fig 1). The software designed for the Emergency Monitoring Center(s) allows to trace simultaneously a large number of mobiles This software consists of a cartography application, a user information system and a PRODAT control module It allows to visualise the position of the mobiles on the maps at three different scales and to retrieve on-line information from the mobiles. The entire software application works under Microsoft Windows 3 1

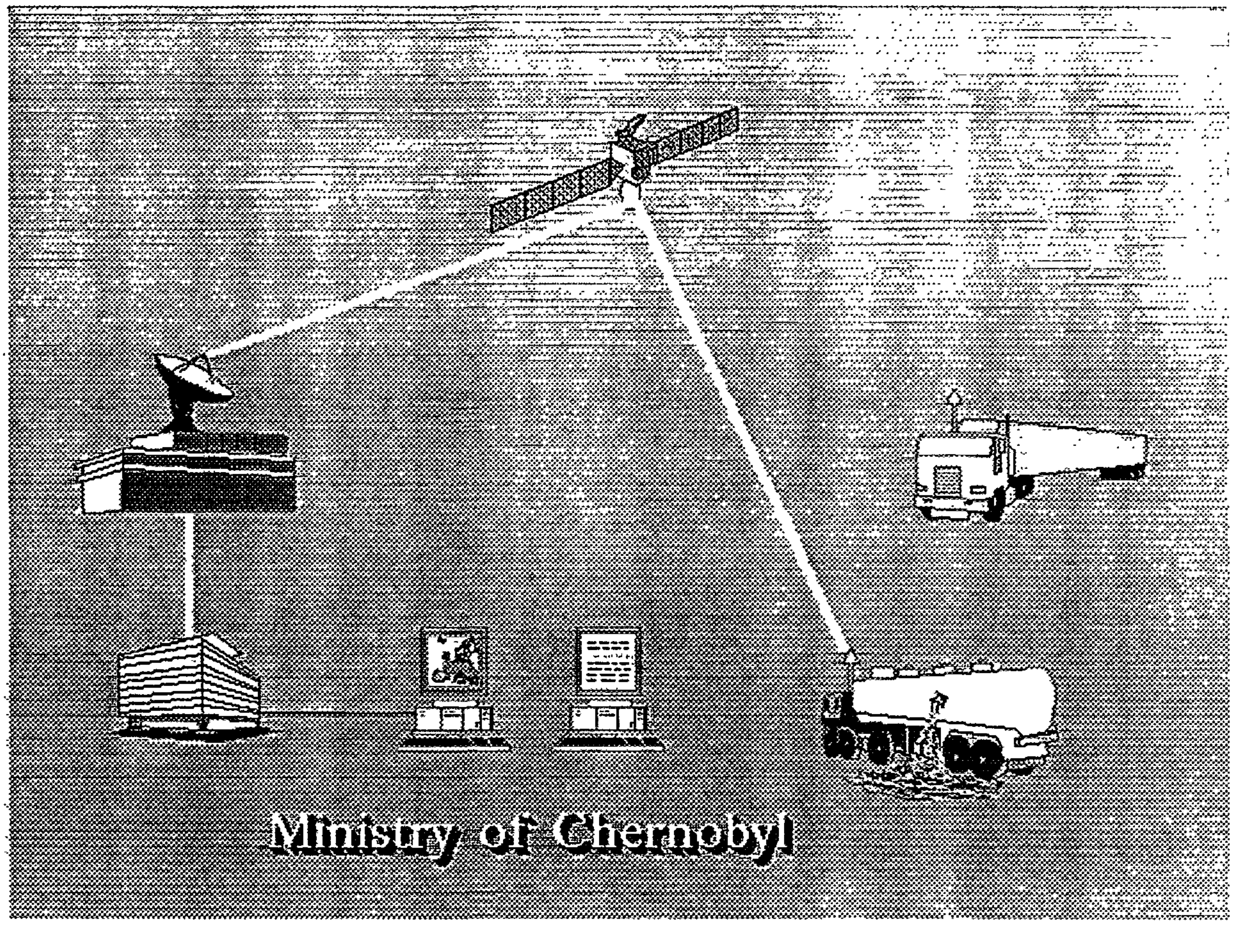
Additional experiments were carried out with a Radiation Reconnaissance aircraft. The reconnaissance flights took place at an altitude of 100 m with a maximum speed of 160 km/h.

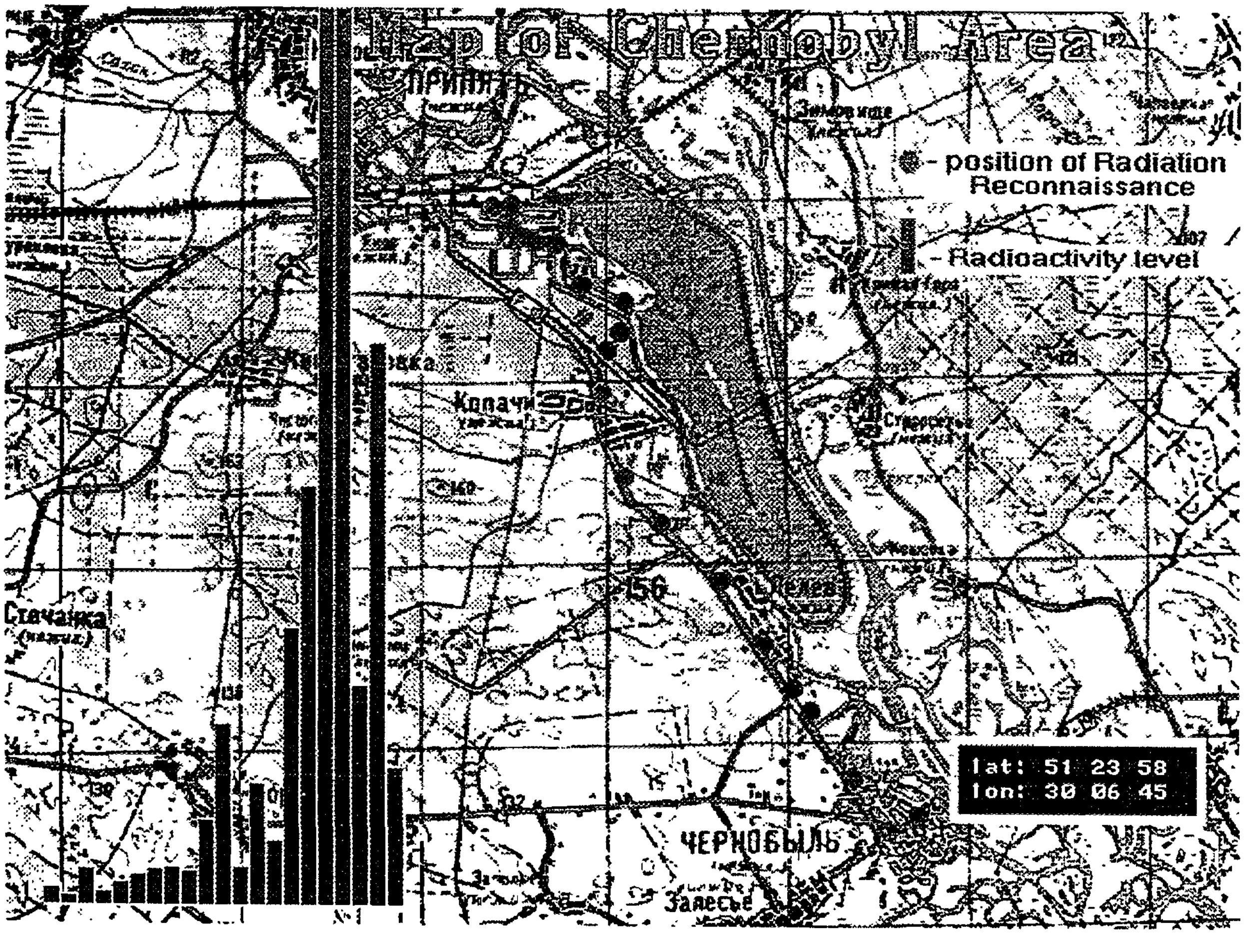
The experiments demonstrated the reliability of satellite communications provided by the PRODAT-2 system to relay sensor data from plane and from ground mobiles

In case of emergency situation causing transboundary propagation of the radiation (forest fire, dust storm), a key issue is to measure the meteorological parameters (direction and speed of wind) in order to predict the patern of the contamination and therefore to trigger all necessary actions to protect the populations.

FIAR has proved experience in using PRODAT-2 for Meteorological Departments in Italy and Germany. Similar use in the Chernobyl Exclusion Zone is now under consideration.

So, sensors data and meteorological data, collected by the same communication system, can be combined in the Emergency Monitoring Centers to predict the contamination evolution thanks to mathematical prognosis models. From there on, preventive actions can be initiated


Ministry of Chernobyl


Map of Chernobyl Area
- position of Radiation Reconnaissance
- Radioactivity level
lat: 51 23 58
lon: 30 06 45
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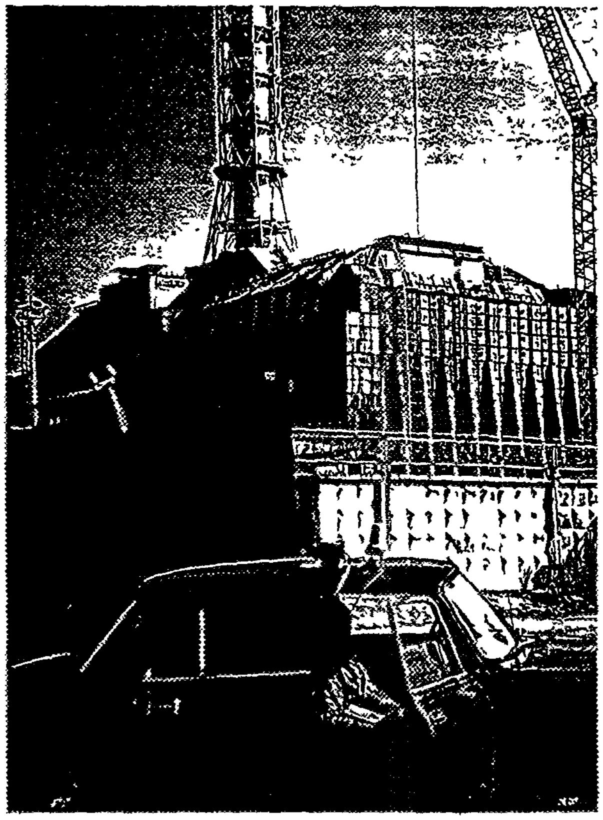
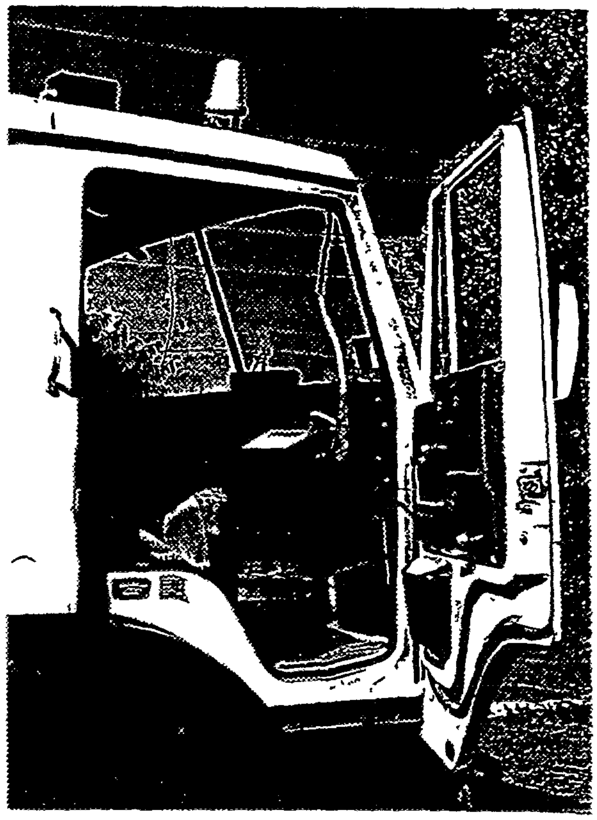
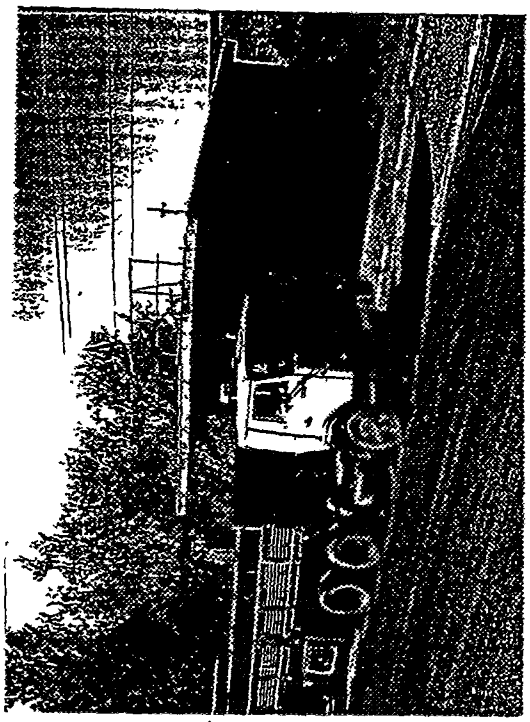
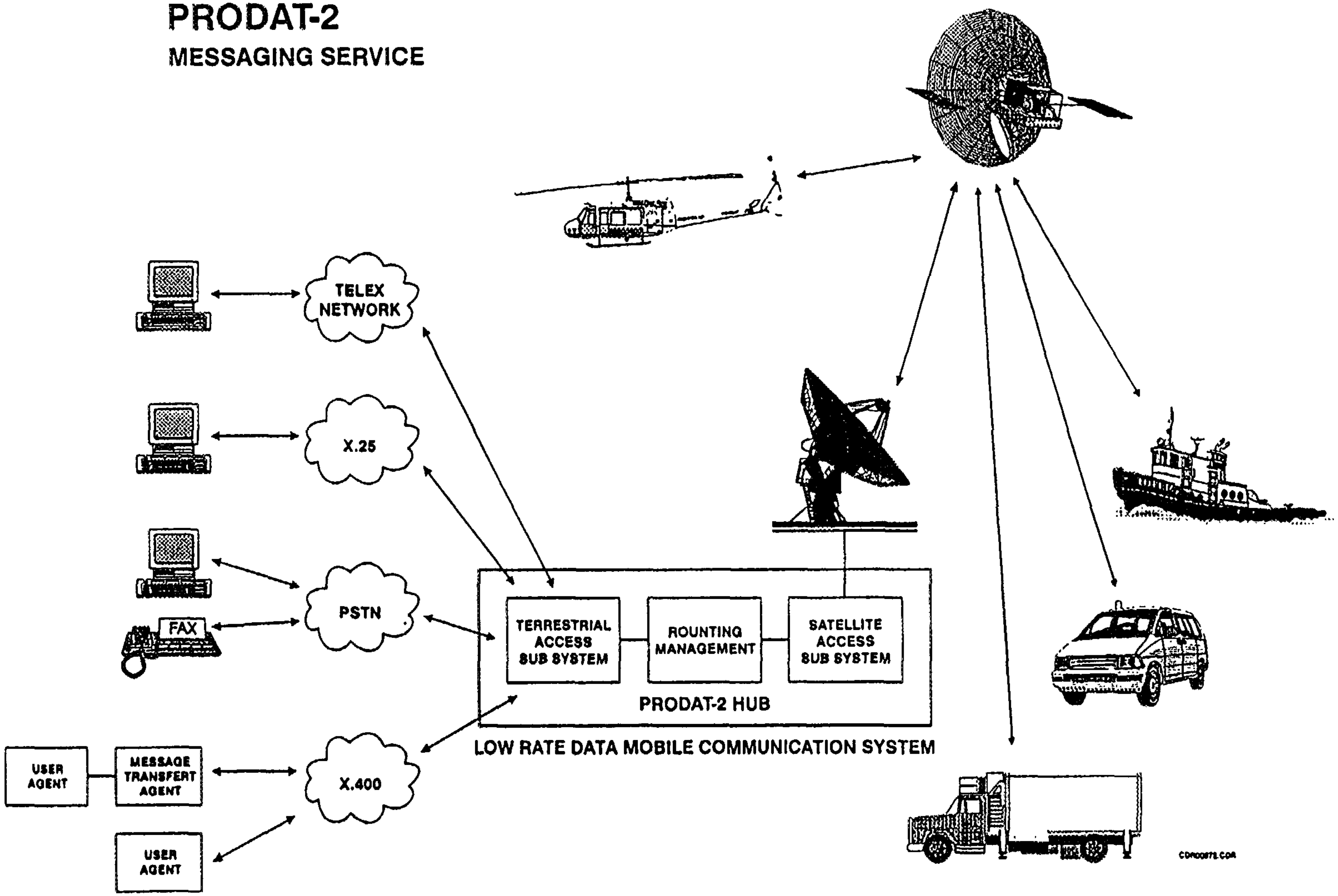






PRODAT-2
MESSAGING SERVICE



On request of the Administration of the Tchernobyl Exclusion Zone, the PRODAT-2 system was also used to monitor transportation of radioactive materials inside the Zone

Photos 2 and 3, taken near Ditjtki Control Post, show a specialized truck dedicated to radioactive waste transportation, equipped with a PRODAT-2 MES and a radiation sensor Antena and radiation sensor were installed on the roof of the cabin of truck (photo 3) The position of the truck and the level of radioactivity were remotely monitored via satellite communications in the Kiev Emergency Monitoring Centre on a digital map of the Exclusion Zone

The positive experience of PRODAT system for radiation monitoring in the Chernobyl Exclusion Zone has led to the concept of a Global Satellite Emergency Monitoring System aiming at the control of the Hazardous Industries

The first steps in this direction have already been taken in Ukraine PRODAT-2 system has been applied to monitor the transportation of radioactive waste and hazardous chemicals Now the application of this technology to monitor nuclear stations, hazardous chemical factories and pipe-lines is under consideration

XA9745851

RADIOACTIVE POLLUTION OF THE GROUNDWATER AROUND THE CHERNOBYL NPP

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Destroyed unit #4 of the Chernobyl Nuclear Power Plant (Ch.NPP) and adjoining territory is the most serious source of radionuclides in the Chernobyl exclusion zone According to estimates of the Kurchatov Institute of Nuclear Research of 1986, the "Shelter" above the destroyed reactor contains about 96% of 192 tones of nuclear fuel loaded in the #4 reactor before the accident. About 0.3% of the fuel is dispersed over the industrial ground of the Ch.NPP, while the rest of fuel is deposited at larger distances from the reactor. The Inter-Disciplinary Scientific and Technical Center (ISTC) "Ukritie" evaluated recently the amount of fuel inside the "Shelter" in 130±50 tones.

The most probable radionuclide migration and exposure pathways from the "Shelter" and adjoining industrial ground of Ch.NPP are atmospheric pathway (transport of radioactive aerosols) and groundwater pathway (subsurface transport of radionuclides dissolved in groundwater). Below we will briefly review data related to radionuclide migration by groundwater pathway from the " Shelter" and industrial ground of Ch.NPP. This pathway is particularly important because the Ch.NPP is located close to the surface water bodies (i.e., cooling pond of Ch.NPP, Pripyat River). Contaminated groundwater discharges to local lakes in the floodplain of the Pripyat River.

The industrial ground of Ch.NPP is located on the first terrace of the Pripyat River, composed of the middle quaternary alluvial deposits. Alluvial deposits consist from fine to medium grained quartz sands. The depth to groundwater from the ground surface is about 5 m. Hydraulic conductivity of sediments vary from 2 m/day to 15 m/day, with an average value of 10 m/day. Hydraulic gradients are estimated at 0.0008-0.0012.

There are several sources of radionuclide migration to groundwater at the site. First, the atmospheric water is accumulating in rooms below the destroyed reactor, and is seeping through the concrete basement to groundwater According to data of the ISTC "Ukritie" this water contains high concentrations of dissolved radionuclides. In particular ^{90}Sr concentration in water reaches 2.3×10^6 Bq/L. The other source of radionuclide migration to groundwater is reactor fuel dispersed over the industrial ground, which was covered during site clean-up in 1986-87 by a several meter sick cover of gravel and concrete

Groundwater monitoring system of the Ch.NPP consists of 28 observation wells for radiological sampling and 62 piezometers for measuring groundwater levels. Screened intervals in wells are located at 7 m depth below the groundwater table Monitoring wells have a steel casing. The observation wells are sampled regularly for total γ-activity. If control level of γ-activity is exceeded, the sample is analyzed for separate radionuclides

In 1995 we performed ground-water sampling of monitoring wells and piezometers for ^{90}Sr, ^{137}Cs and inorganic chemicals The special attention was paid to quality assurance - quality control requirements All wells were pumped before the sampling The pH of the pumped water was monitored during the sampling The samples were collected after stabilization of pH, which indicated that stagnant water is removed from a well

The results indicate that groundwater is throughout contaminated by ^{90}Sr and ^{137}Cs The elevated concentrations are found in the vicinity of the "Shelter" The average concentrations of ^{90}Sr constitute 5-10 Bq/L, while maximum concentration is 3600 Bq/L. The background levels of ^{137}Cs in groundwater at industrial ground constitute 2-5 Bq/L, while maximum concentration is about 300 Bq/L. (For comparison ^{90}Sr drinking water standard (DWS) in Ukraine is 3.7 Bq/L, and ^{137}Cs DWS is 14.8 Bq/L). The concentrations measured in groundwater are relevant to depth of about 7 m in the aquifer below the groundwater table. Because radionuclide sources are located at the ground surface, it is expected that the upper portion of the aquifer is contaminated by radionuclides in much higher concentrations.

The groundwater sampling revealed also groundwater contamination by chemicals. Permissible concentrations of toxic metals in groundwater are exceeded for lead by factor of 2-3, for nickel - by factor of 8, for manganese - by factor of 13, for iron - by factor of 50-100.

The data presented above indicate that groundwater contamination in the zone of the "Shelter" and industrial ground of Ch.NPP is a serious issue. Problem of groundwater contamination must be considered when developing plans for decommissioning the Ch.NPP and converting "Shelter" into ecologically safe system. The first priority task is developing a full and reliable groundwater monitoring network at the site. The observations must be carried out at the multilevel observation wells. The sampling program must be extended and include measuring not only radioactive contaminants, but also hazardous chemicals.

PREDICTION OF RADIONUCLIDE MIGRATION IN THE PRIPYAT RIVER AND DNIEPER RESERVOIRS AND DECISION SUPPORT OF WATER PROTECTION MEASURES ON THE BASIS OF MATHEMATICAL MODELLING

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1 INTRODUCTION

Dnieper River watershed have been heavy contaminated by radionuclides under the influence of the Chernobyl accident Significant part of radionuclides fallout took place on the watershed of Pripyat River Chernobyl NPP stays near its bank approximately near 30 km from the Pripyat River outflow to the Kiev Reservoir of Dnieper river The fllodplain territory near Chernobyl NPP and surrounding watersheds are heavy contaminated by ^{137}Cs and ^{90}Sr The spots of ^{137}Cs are in the upper Dnieper watershed in Russian and Belorussian territory and on whole Pripyat watershed This surface contamination leads to the permanent influx of ^{137}Cs and ^{90}Sr into the Kiev Reservoir and consequent radionuclide transport through the whole cascade of six Dnieper reservoirs The magnitude of this distributed source increased during each spring floods generated by snow melting (1987-1996) and by high rainfall floods in Pripyat river (October 1987, July 1988, October 1990, July 1993) As result the Ukrainian population consuming Dnieper water down stream- from Kiev up to the Black sea are under the impact of the Chernobyl radionuclides More than 20 million people inhabited there consuming a drinking water (about 9 million people) Also the fishery and irrigation agriculture products are linked with water usage from the Dniper's reservoirs Therefore the polpulation even nowadays 10 years after the accidfewnt are very sensitive for this problem

Since May 1986 in Kiev in the Institute of Mathematical Machines and System Problems, Cybernetics Center of the National Academy of Sciences of Ukraine has been started the development of the computerised system for processing of Dniper basin radiological monitoring data and modelling of radionuclide dispersion in rivers and reservoirs For this work it was established the Interdisciplinary Working Group that joints the specialists from the State Committee of Water Resources, State Committee of Hydrometeorology, National Academy of Sciences and other Ukrainian institutions The objectives of the computerized system development were formulated by the State Emergency Commission and later by the Ukrainian Minchernobyl as follows

- reliable evaluation of the surface water contamination at Pripyat River and Dnieper River on the basis of monitoring data from the different institutions,
- seasonal and long-term prediction of the surface water radioactive contamination,
- decision support for the aquatic post-accidental countermeasures, directed to diminish the radionuclides fluxes from the Chernobyl area through the Pripyat River and Dnieper Reservoirs,
- decision support for the countermeasures directed on changes in the water assumption

The first operational version of the computerized system was running since September 1986. It has been used for the forecasting of radionuclides dynamics in the Dnieper Reservoirs during the period of the Autumn heavy rainstorms, as also for the operative evaluation of the efficiency of several aquatic countermeasures. In 1987 the system was first time used for predicrion the Dnieper resrvoirs contamination during the spring flood. Within the decade after the accident the system was used, permanently improving and refining, for the radionuclide concentration prediction in water bodies as also for the water protection decision support [1-5]. The main results of this work are overviewed in the paper.

2. ACCIDENTAL CONTAMINATION AND WATER PROTECTION COUNTERMEASURES

The monitoring system for water contamination measurements have been established on the Dnieper-Pripyat aqautic system after the Chernobyl accident [6,7]. The highest level of radioactivity in the water of Pripyat river was observed during the initial period after the accident. Over the time from 1986 to 1994 radionuclides contents in the river flows are permanently decreased in general, but during each high water period its concentration in the water temporary increased under the wash-off and erosion phenomena, creating a secondary contamination of the water masses. Therefore, the ratio between Sr-90 and Cs-137 in water flow have been changed significantly as well as the ration between its suspended and soluble part in the water (Table I.)

Table. I. Annual total influx of ^{137}Cs and ^{90}Sr (Ci[1]) to Kiev Reservoir from Pripyat River and Dnieper River.

Years	^{137}Cs in solute	^{137}Cs on sediments	^{90}Sr total
1986	2261	359	1034
1987	505	213	496
1989	255	110	338
1991	68	65	511
1993	69	47	425

[1] 1 Ci= 37 GBq

The main feature of the radionuclide release from the contaminated watersheds to the Kiev reservoir within 10 years after the accident is the significant diminishing of the ^{137}Cs influx to the reservoir, however ^{90}Sr washing out to river net continue to be on practically the same level. Since 1992 the rate of ^{90}Sr release to Pripyat River was diminished due water protection measures (dam construction) on floodplain near Chernobyl NPP.

The difference in the behaviour of the radionuclides appears also in the phenomenon that large part of ^{137}Cs, as well as some other radionuclides, are associated in water with suspended particles. The average size of suspended particles of the river's flow varied from 0.02 mm in low water period and to 0.25 mm during the floods. The total amount of suspended sediments in the river flow with size particles less than 0.05 mm was presented approximately in range 55-60 % of total. On the contrast, the bed sediments of the Pripyat river consist almost exclusively of the sands with very small amount of silt and practically without clay size sediments. The ratio of ^{137}Cs amounts transported with suspended sediments to ones in solute has the tendency to increasing (Tabl.I) due to decreasing of Cs-137 contents in mobile forms in upper surface layer of the catchment because of its fixation and vertical migration in soils.

The specific of radionuclide transport difines the strategies of aquatic countermeasures A lot of remedial strategies that has been proposed may be classified as follows

A Measures in drainage area
a) Removal of contaminated soil,
b) Alternations in the catchment area to minimize the run-off of radionuclides from land to water, e g , planting of trees, digging of channels/ditches, or adding the chemicals to bind the radioisotopes (e g , lime, potash or dolomite),
c) Prevention of flooding most contaminated territories attached to a water body (e g , floodplain dams),
d) Construction to prevent radionuclide transport to surface water bodies by ground water flow (e g contra-seepage wall in soil)

B Measures in water bodies
a) Constructions to increase the sedimentation of contaminated suspended materials in rivers (e g a quarry - a bottom trap for contaminated sediments, dams, ditches and spurs)
b) Construction to separate most contaminated parts of the water bodies from a main stream (e g , dikes and dams dividing the water bodies),
c) Dredging of contaminated deposits,
d) Change in mode of the Dnieper reservoir management to optimize it on radionuclide concentration criteria
e) Change in drinking water intakes , e g recommendation to switch on other water supply sources

The efficiency of the countermeasures depends from the taking into the account the above described specific of raduionuclides transport in dilute and with suspended sediments for different kinds of radionuclides A lot of non efficient measures were provided in first emergency phase of water protection activities The description of the different phases of countermeasures activities and examples of non-efficient countermeasures are presented in [8] Since September 1986 when first version of modelling system have started to work in the Cybernetics Center the evaluations of countermeasures efficiency were provided there to support the Emergency Commission decisions The positive results of the system implementation was not only recomendation for efficient countermeasures, however also the recomendation to stop non-efficient projects

3 MATHEMATICAL MODELS

Due to the objectives of the computerized system to support the water protection measures the radionuclides dispersion in the Pripyat River and Dnieper Reservoirs should be simulated within the wide range of temporal and spatial scales—from tenth of meters to thousand kilometers and from second to tenth of years To simulate processes in such wide range of scales the set of mathematical models have been formulated [1-4] which equations have been derived from the equations of the basic three-dimensional model by their averaging over the different scales

Each model includes submodel of hydrodynamics (hydraulics), suspended sediments transport submodel and radionuclides transport submodel In the suspended sediment transport submodel the rate of sedimentation and the resuspension rate are calculated as the function of the difference between actual suspended sediment concentration and equilibrium concentration relevant to the transport capacity of the flow The later is calculated on the base of semi-empirical relations

The radionuclides transport submodels describe the dynamics of concentrations of radionuclides in solution, in suspended sediments and in bottom depositions For describing the adsorption/desorption and diffusion contamination transfer in the systems "solution - suspended sediments" and "solution - bottom deposition" the Kd approach has been used For a more realistic simulation of the kinetics of the processes the exchange rates between solution and particles was taken into account by additionally taking the exchange rates between solution and particles into account for simulation kinetics processes The adsorption and desorption rates assumes not to be equal The contamination exchange between bottom deposition and suspended sediment is describing taking into account sedimentation and resuspension processes

The modelling system nowadays includes following models

WATOX - box model, which variables are averaged over compartments that as usual represent whole reservoir or it's large section The resulting set of the ordinary differential equations describes the dynamics of the water volume in a box and the compartmentally averaged value of the suspended sediment concentration, the concentration of the radionuclide in solution, on suspended sediments and in bottom deposition The results of the prediction of the radionuclide concentration within flood period depend on the operation mode of the reservoirs, i e from the changes in the water levels at the Hydropower Plants dams The optimization methods are used to provide choices of the reservoir system operation mode under the water quality criteria

RIVTOX-one dimensional river model, is used to simulate radionuclides transport in networks of river channels generated by the direct pollutant release into the river or by the washing out of radionuclides from the catchments The variables in RIVTOX which describe flow, suspended sediments and radionuclide dynamics are averaged over the river channel crossections A 'diffusion wave' model is used to describe water discharge and surface elevation dynamics, that has been derived from the one-dimensional Saint-Venant's equation The advection-diffusion equation is used to describe suspended sediments transport in the river channel The dynamics of the upper contaminated bottom layer is driven by the equation of bottom erosion The high order accuracy finite-difference methods (FDM) are used to solve "diffusion wave" equation and advection-diffusion equations that describe transport of suspended sediments, radionuclides in dilute and radionuclides adherent to suspended sediments The ordinary differential equation simulate the radionuclides dynamics in the upper contaminated bottom layer

COASTOX is two-dimensional lateral-longitudinal model developed to simulate depth averaged concentration of radionuclides in solute, suspended sediments and in bottom depositions of reservoirs, floodplains and coastal areas The model is used to analyze radionuclide dispersion in water bodies with significant spatial variations of the concentrations (vicinity of the releases, transport above inhomogeniously contaminated bottom, etc) The model describes currents, sediment transport advection-diffusion pollutant transport, radionuclide - sediment interaction The FDM are used to solve the model's equations

VERTOX is two-dimensional vertical -longitudinal model developed to simulate radionuclides transport in the vicinity of the abrupt depth changes- such as bottom traps for contaminated sediments and other engineering constructions The model equations have been derived by the averaging of the equations of basic 3-D model over the river channel width The numerical solution of the models equations are obtained by FDM

THREETOX is three dimensional model developed to simulate radionuclide transport with large vertical and lateral variability of flow parameters (deep lakes and reservoirs, cooling ponds of nuclear power plants) The model implementation requires a lot of input data and computer resources, therefore it is used only in situations when spatial variability of parameters do not permit use more simple approaches

WATOX and RIVTOX models where validated within IAEA/CEC VAMP programme [9] COASTOX was verified within CEC JSP -1 project[10] The sediment transport and bottom erosion modules of VERTOX were tested on the base of laboratory experiments data [3] THREETOX is under testing studies now

4 PREDICTION OF THE PRIPYAT RIVER-DNIEPER RESERVOIRS RADIONICLIDE CONTAMINATION

The predictions of ^{137}Cs and ^{90}Sr concentration in the Dnieper reservoirs during spring flood were prepared in February-March each year since the accident by applying the WATOX code[1,4] The predictions also was developed during the high rainstorm flood and other extremal events at Pripyat River watershed [11] The data of the watersheds contamination density and the averaged values of the radionuclide wash off coefficients were used to predict ^{137}Cs and ^{90}Sr concentrations in the tributaries released into the reservoirs Since 1986 the level of ^{137}Cs concentration in the Dnieper reservoirs decreases (close to the pre-accident values in the southern reservoirs) due to low magnitude of the spring floods and as a result of the diminishing of ^{137}Cs wash-out coefficient The coefficient of ^{90}Sr wash out does not diminish in the same manner Therefore the ^{90}Sr contamination remains most significant problem for high spring floods in the Pripyat River - Dnieper River system The simulation of processes on the floodplain at the Chernobyl NPP have been supplemented by forecasting of ^{90}Sr dispersion in the Dnieper reservoirs The seasonal and short term predictions are in reasonable agreement with the measured data for the spring floods, rainstorm floods, consequences of the radionuclide releases from the Pripyat floodplain as results of the ice jams in winter 1991 and 1993

The computerized system is used for the prediction of Dnieper reservoirs contamination during 1996 spring flood The unusual large amount of snow in the winter 195-1996 at nortnern part of Ukraine put public attention to the problem of radionuclide contamination of Dnieper reservoirs For the most probable estimation of the magnitude of hydrograph of the Pripyat River that have been done by the Ukrainian hydrometeorological service at middle of march - 1900-2100 cub m /s the simulation gives ^{90}Sr concentration at 80 pCi/l in the Pripyat river and its increasing from 2-4 pCi/l to 20 pCi\l near Kiev at the end of April This upper estimation of the maximum of concentration is several times lower than Maimum Permissible Level - 100 pCi/l The results of simulation was presented to State Emergency Comission and was used for public information

To estimate the collective dose for population of Ukraine from the consumption of Dnieper water during 70 years after the accident (till 2057) WATOX code was used in the version based on three months averaged input data The three month averaged discharge of the Dnieper River, Pripyat River and tributaries to the Dnieper Reservoirs since 1895 were used to create hydrological data base for a long term prediction The scenario of the worst radiological conditions should be based on the sequences of high runoff years since 1994 The constructed set of the hydrological data used 1970-1992 (high runoff period) and then 1912-1950 (low runoff period) as a "hydrological forecast" for 1994-2057 For the prediction of radionuclides concentration in the tributaries to the Kiev Reservoir the regression relations between concentration and water discharge were constructed based on the experimental data and evaluation of the dynamics of washing -out coefficients governing by the leaching from fuel particles and by the decay and the percolation into the soil The simulated results demonstrate that the large southern Kakhovka reservoir, damping the seasonal oscillations, will have after some years practically the same level of ^{90}Sr concentration as the Kiev reservoir In the last three month averaged concentration will change from 27 pCi/l in the initial period to the 3-5 pCi/l in 2056 These data and data of the better from radiological conditions hydrological scenarios was used to calculate dose for the development of the post-Chernobyl countermeasures in Ukraine [12]

5 MODELLING SUPPORT OF THE WATER PROTECTION MEASURES

5.1. Optimization of reservoir management

The box model WATOX includes the optimization module to provide choices of the reservoir operation mode on the base of water use and water contamination criteria The optimization efficiency increases with the diminishing of the ratio of spring flood volume to total reservoirs volume The results for the average spring flood demonstrate that maximum diminishing of the concentration in the reservoirs could be near 25% of the peak value within the hydropower production restrictions The maximum diminishing (up to 50% of the peak value) could be achieved for low water flood (probability of exceeding PE=95%) The model is implemented in the State Committee on Water Resources for Dnieper Reservoirs management

5.2. Countermesures to increase radionuclide sedimentation

The VERTOX and COASTOX models were used to evaluate the efficiency of the countermeasures proposed to diminish the radionuclide concentrations in the Dnieper reservoirs The demonstration of low efficiency of the large scale hydraulics projects for Kiev Reservoir -the construction of the new dam through the reservoir and submerged dike near Hydropower Plant, was background to stop this expensive projects

The VERTOX model was applied used to simulate the efficiency of the bottom traps for contaminated sediments in the Pripyat River channel [3] It was demonstrated that the selectivity of the traps for sedimentation in depend of radionuclides distribution through the size fractions of the sediments grains ^{137}Cs is transported by the finest suspended sediments that provides non-efficiency of such countermeasures

5.3 Countermeasures on the Pripyat River floodplaine

One of the most powerful source of ^{90}Sr contamination of the Pripyat water and as result in all down flow Dnieper reservoirs is the fuel particles fallout on the Pripyat river floodplain North-Eastward from the Chernobyl Plant Near 10000 Ci of ^{90}Sr were deposited here on the territory 4 km*10 km The simulation of the potential flooding of this territory has been provided since 1989 on the base of COASTOX computer code [1,2,4] This territory has not been flooded till 1991 because of low spring floods during this period

The simulation of the floodplain flow has demonstrated that the most dangerous situation, causing large increases in radionuclides concentrations is a spring flood with a maximum discharge of 2000 m /sec The probability of exceeding (PE) this flood magnitude for the area considered of the Pripyat river is 25% During such spring flood the water covers all parts of the contaminated floodplain, but water depth is less then one for floods with lower PE It was demonstrated [1,2] that during such flooding the concentration of ^{90}Sr would increase from 50 pCi/l at inlet crossection (10 km upflow Chernobyl NPP) to 250-270 pCi/l at outlet crossection (the Yanov Bridge near Chernobyl NPP) due to the interaction with the contamination in the bottom depositions The construction of the special dam around the contaminated area on the left bank of the Pripyat river has been recommended in 1990 on the base of simulated results as the optimal countermeasure to prevent release from floodplain

In January 1991 before starting of the dam construction ice-jam was formed in the Pripyat river channel between Yanov Bridge and the town of Chernobyl As a result the Pripyat floodplain near the Chernobyl NPP was covered by water for the first time after the accident Maximum concentration of ^{90}Sr near the Yanov Bridge increased to the values 250-300 pCi/l This way the results predicted during simulation of countermeasures effectiveness has been confirmed by a wide scale natural experiment During the flooding the modelling system was use for real-time simulation of the situation on the floodplain on the base of COASTOX model and for prediction dynamic ^{137}Cs of ^{90}Sr concentration in the reservoirs and especially near Kiev on the base of WATOX model Due to dilution and dispersion of contamination in the reservoir the maximum concentration on the way from River Pripyat mouth to Kiev HPP (more than 70 km) diminished from 200 to 30 pCi/l

The forecasts (confirmed later by direct measurements) have been presented to the State Commission It was used to make optimum change in February1991 to the municipal water supply arrangements without having to use water from the River Dnieper The dam preventing future flooding of the considered part of the Pripyat floodplain has been constructed till 1992 spring flood Recently small dam have been constructed on the rgite side of the floodplaine The simulation demonsttrates that in case whithout this dams constructions the concentration of ^{90}Sr at Kiev Reservoir could be three time more (up to the 60 pCi/l) that it predicted now, after this countermeaasure fulfillment

CONCLUSION

Within the decade after the accident the computerized system was improved and used for the radionuclide concentration prediction in water bodies as also for the water protection decision support

Main practical outputs of the system are as follows

- background of the dam construction at the Pripyat River floodplain at city of Pripyat,
- negative conclusions for the several non-efficient projects,

- predictions of the seasonal variations of radionuclides concentration in Dnieper reservoirs as results of the follows hydrological events spring floods generated by snow melting, and summer - autumn floods generated by rainstorms, flooding of the territories at Chernobyl NPP due to ice jams in the Pripyat river,
- long-term forecasting of radionuclide concentration in Dnieper reservoirs for life-time dose calculation taking into account radionuclide dynamics on watersheds within different hydrological scenario.

The experience of the model application for prediction of rivers and reservoirs contamination and water protection decision support after the Chernobyl accident is used to develop the hydrological module of the European comprehensive decision support system for nuclear emergency - RODOS

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INFORMATION SYSTEMS IN CHERNOBYL ACCIDENT AFTER-EFFECT ELIMINATION: ON THE WAY FROM YOUTH TO MATURITY

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10-years period of Information Systems in the Chornobyl Accident after-effects elimination (these systems we name Chornobyl Information Systems (ChIS) for simplicity of reference) creation is analyzed. It is clamed that CiIS are introducing into the maturity phase now. The paper consists of Introduction, four paragraphs and Conclusion.

Short history of ChIS creation on the example of radoiecological component is described in Introduction. Two phases: youth and maturity, are identified. The youth phase is divided on three periods: 1986-1988, 1988-1992, 1993-1995 The maturity phase has started in 1994 with accepting of new Conception of ChIS implementation. Main characteristics of each phase and period are described.

The Conception of Mature ChIS is described in first paragraph. Key elements of Conception:

- Conception is based on object-oriented approach. There are four types of objects: active persistent, active dynamic, passive persistent, and passive dynamic. Each component system of any ChIS is an object, compounded from objects of these four classes. This object is instance of class with some predefined structure.
- Each component information system consists of three contexts: organizational (or usage world), infological (or subject world), datalogical (or system world).
- Mature ChIS consists of scientific-methodological, industrial and managerial components
- Scientific-methodological, industrial and managerial components are connected into Wide Area Network (WAN).
- Mature ChIS is distributed system Only passive persistent objects can be distributed in WAN
- The distribution is described through the Federation of autonomous databases conception
- Mature ChIS consists of two territonal levels national and regional

The Methodology of Mature ChIS development is described in second paragraph Key elements of Methodology·

- First of all it is needed to change the organizational objects, so education and training of users are principal
- There are four stages of each principal component object (system) construction requirements and needs analysis, system analysis, design and implementation
- Popular Object Modeling Technique OMT is used for system analysis and design stages
- The distribution of heterogeneous passive persistent objects will be possible if generalized standard passive persistent objects will exist This element is connected with the creation of different metalevel objects standards, methodics, normatives
- Principal components can be created only after pilot-projects and case studies

The implementation of some Mature Radioecological ChIS elements is described in third paragraph First versions of two specific Mature ChISs are created:

- Radioecological Geographic Information System (RGIS1 project) for Department of Population Radiation Protection of Ukrainian Ministry of Chornobyl as managerial user and Scientific GIS Laboratory, created by Ministry and Main Administration of Geodesy, Cartography and Cadastre, - as scientific-methodological user,
- Management Information System, based on Geoinformation Technologies (SMIS1 project) for Administration of Chornobyl Exclusion Zone as managerial user

Discussion is represented in fourth paragraph The key point of this paragraph is possible strategy of moving on the way to mature ChISs in complex economic situation of Ukraine

XA9745854

THE FAST GAMMA SPECTROMETRIC METHOD OF THE Am-241 DETERMINATION IN CHERNOBYL RESTRICTED ZONE SOILS

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1 INTRODUCTION

The known methods of the ^{241}Am contents determination in environmental objects [1-4], as a rule, is based on ion-chromatographic or extraction separation techniques This approach reflects widespread opinion, that only the α–spectrometric analysis termination is suitable to ensure necessary sensitivity of the overall method of ^{241}Am activity determination Really, the minimal detectable activity for such methods is about 0 05 Bq/kg (considering that Am is usually concentrated during separation procedure) However, because of α–spectrometry does not permit to separate the α–peaks of the ^{241}Am and ^{238}Pu. but also in view of high requests to the α–spectrometric specimen purity, the multistage and laborious chemical procedures to separate ^{241}Am from plutonium radionuclides and other elements (with a thorough control of each separation stage) are needed [3,4]

Based on its γ–radiation, express and non-destructive, though less sensitive ^{241}Am determination method is known also Considering the fact, that yield of the γ–quanta with energy 60 keV per α–decay is rather high (~30 %), there is an opportunity of the direct ^{241}Am activity measurement without any chemical separation [5] In quoted work it was possible to reach the ^{241}Am detection limit of 7 4 Bq/kg within an error of 22 % The method is based on self-absorption accounting in sample matrix and assumes an uniform distribution of the radionuclide in soil, which is more characteristic for global fallout and does not suitable for specific character of environment pollution due to Chornobyl accident

The intention of the present work is to investigate the possibility and restrictions of the γ–spectrometric ^{241}Am activity measurement application for the ChNPP exclusion zone soil samples

Direct and non-destructive γ–spectrometric ^{241}Am activity measurement of a soil samples from exclusion zone is accompanied with a number of factors, negatively influencing on the accuracy and reproducibility of the analysis results Besides strong self-absorption in matrix, the most meaningful factors are

- the significantly more high activity levels of cesium radioisotopes featuring the ChNPP exclusion zone samples The Comptone component of its radiation drastically worsens the ^{241}Am peak registration conditions, causing low net peak area evaluation accuracy,
- the presence of the fuel hot particles in soil samples, that owing to their inherent tendency toward stratification at any mechanical treatment of the dry sample (due to its higher density - up to 10 g/cm^3), both creates hardly overcomed methodological obstacles at all stages of sample preparation and introduces an unknown uncertainty into the measurement results The last is due to hot particles are not uniformly distributed in measured sample, and "are going" near to the bottom of a measurement vessel (i e near to detector) at any mechanical effect on the specimen, so making correct self-absorption accounting not achievable

Both the presence of "hot particles" (which has generally unknown distribution on sizes and within the sample matrix) in the soil samples from ChNPP exclusion zone and significant self-absorption in samples matrix, caused by the small energy of ^{241}Am γ–quanta (4 cm of average density soil can absorb up to 96% of such photons) requires careful study of the applicability and accuracy of such express Am determination method for analysis of exclusion zone soil samples

2 METHOD DESCRIPTION

In connection with above-stated, but also due to the necessity to increase the expressness of ^{241}Am determination methods for the ChNPP exclusion zone environmental objects, we try to develop a fast determination method, in which the separation of americium from other α–emitters and most of ballast ions is not required The method is based on the γ-spectrometric activity measurement of sample solution, obtained after acid leaching of sample and following simple group separation from Cs, K and Sr radionuclides (that significantly decrease the ^{241}Am γ–peak base line) Also, sample transferring into solution allows to assume uniform Am distribution in the measured volume

The uncertainty, caused by hot particles presence in the initial sample (but also incorrectness in selection of a small "representative" weight for the analysis) can be eliminated by the dissolution of obviously more representative large weights (up to 200 - 400 g) of the sample Analyzing then a small aliquot, we can exclude this beforehand unknown (and, in some cases, rather high) sample composition uncertainty The known uncertainty due to change of the sample composition caused by transfer into solution (rather small for ^{241}Am, as will be shown hereinafter) and known uncertainty of volume measurement at aliquot taking can be easily accounted Besides dissolution of a large sample permits americium concentrating if necessary

The proposed method of soil samples analysis includes

(a) to ensure sample representativness and override unknown hot particles distribution uncertainty we propose taking into analysis greater sample weight (up to 200 – 400g) without traditional sample preparation procedures,

(b) ashing in muffle at 450 °C for 6 h after air-drying and dry weight determination,

(c) concentrated HNO_3+HCl 3 1 mixture treatment (3 h at the near boiling conditions) at the sample acid mixture volume ratio 1 3,

(d) filtration and repeated treatment of residue as on previous step,

(e) another filtration and washing of the residue with 3 volumes of distilled water,

(f) bringing of joined filtrate and washing waters into known volume, and taking needed (as estimated by overall sample γ-activity) aliquot,

(g) evaporating of an aliquot up to the "wet salts", hot dissolution in 0 1M HNO_3, filtration and then washing–out of the hydrated siliceous residue,

(h) coprecipitation of Am (and another α-emitters) with Fe and Al hydroxides by the carbonate-free ammonia treatment,

(i) centrifugation of hydroxides,

(j) repeated coprecipitation from the decanted supernatant (after acidification to pH<2 and a small volume of $FeCl_3$ solution addition),

(k) repeated centrifugation and supernatant decantation in the same centrifuge tube,

(l) resuspension and another cenrifugation of hydroxides in distilled water,

(m) after washing water decantation, the residue is dissolved in a small volume of 0 1M HNO, transferred into vial for γ-measurement and diluted up to desired volume,

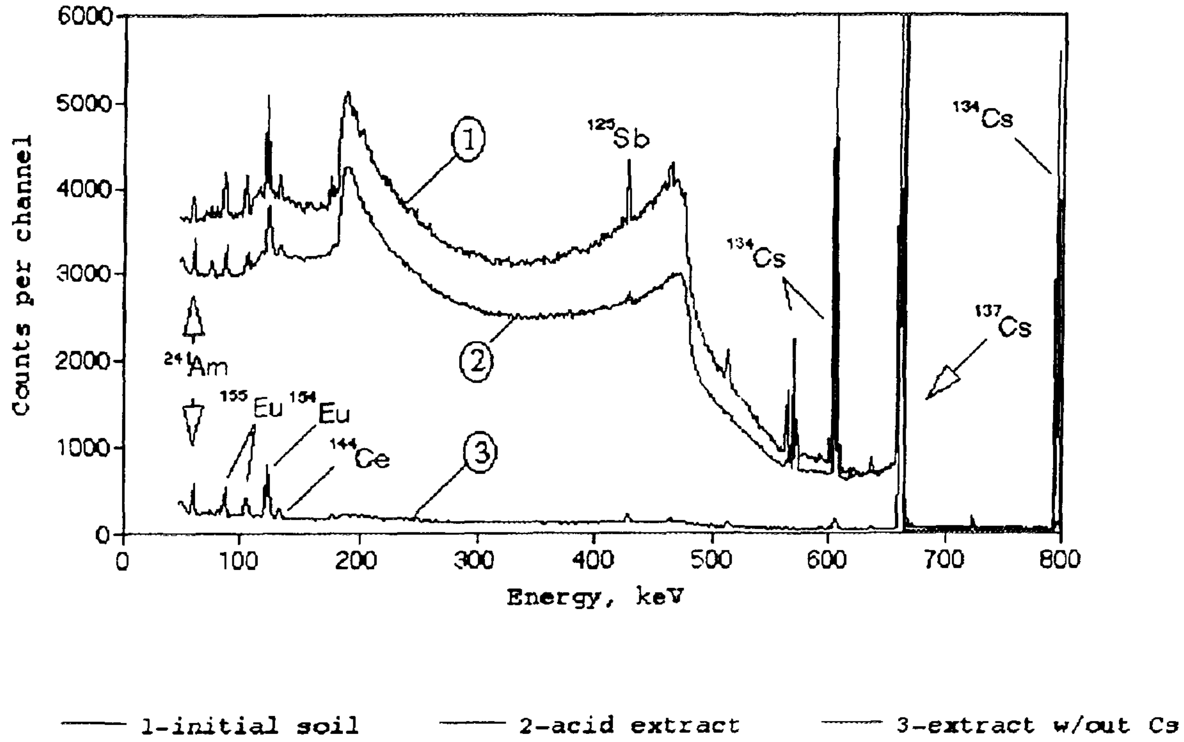
(n) γ-spectrometric measurement and spectra treatment using a standard method

All γ–spectrometry data was obtained using the most common GEM type HPGe detector (CANBERRA GC2518-7500SL) connected with ORTEC Spectrum Master 919 spectrometer and with ORTEC Omnigam software

3 RESULTS AND DISCUSSION

On the drawing, representing changes in the sample spectrum during radiochemical processing, it is visible, that the americium γ–peak is located on a curved line pedestal of the Comptone components of cesium isotopes radiation The intensity of the pedestal is about 10 time exceeding the americium

Gamma spectra of initial soil, its acid extract and extract without Cs



peak intensity, that results in large calculation errors both for base line and, accordingly, for net peak area. Reduction of the cesium emission (and its Comptone component respectively) in the acid extract spectrum as compared to initial sample is caused by partial cesium loss during ashing of sample.

As a result of the proposed sample treatment the signal / noise ratio grows in magnitude ten times and relative uncertainty of the activity measurement is reduced from 18.5 up to 6.4 %. Due to spectra recording conditions improvement, this method allows to reduce the ^{241}Am minimal detectable activity (MDA) with a standard HPGe - detectors from 1.5 to 0.5 Bq/sample that corresponds to the activity levels of 10 - 20 Bq/kg. The MDA evaluation was made for the samples with specific activity of ^{241}Am ≈ 150 Bq/kg, initial activity ratio of ^{241}Am/^{137}Cs ≈ 1 : 300 at the registration time of 10,000 s and a volume concentration factor of 1. If the concentration of a sample solution is applied (the allowable sample concentration factor, probably, does not exceed 20 - 50^{x} in view of the ballast salts added during cesium removal), the least detectable activity value can reach as low as 0.5 Bq/kg. Finally, by using of a specialized low energy region planar type detector with berillium window (like the CANBERRA GL2020R-7500SL, which has ^{241}Am MDA value as soon as three times lower for the same samples), it is possible to approach a sensitivity near to the α–spectrometry sensitivity for a comparable measurement times.

For evaluation of an overall ^{241}Am determination accuracy we had investigate the parallel determinations reproducibility of the large, grinded up to particles size less then 0.5 mm and carefully mixed forest soil specimen (together with the litter) sampled in vicinity of Belaya Soroka village (the edge of north-west trace). Each value represents average of three parallel weights, which were processed and measured separately. The results of this evaluation is represented in Tab. I.

As it is demonstrated in Tab. I, the average determination method uncertainty (don't confuse with the activity measurement error) for majority of the γ–emitters, after dissolution and cesium throwing–out was lowered and for ^{241}Am resembles 3 - 6 % in comparison with 60 - 70 % for the initial soil. A little bit overestimated average values of ^{241}Am contents in the cesium containing samples supposingly relate to the inexact peak area calculation, because Am as it is known, quantitatively coprecipitates with hydroxides of iron and other metals.

Table I.

γ-Emitters activities (Bq/kg) distribution for air-dry soil sample, acid extract, solution of a fraction, coprecipitated with ferric hydroxide and insoluble residue. Evaluation of the ^{241}Am determination *reproducibility and uncertainty on parallel sample replicates.*

Sample No	Sample type	Mass, g (volume, ml)	^{60}Co	^{106}Rh	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	^{241}Am	^{40}K
1 - 3		160 ±0.4	6.9 ±41%	<100	293	1305 ±10%	41056 ±10%	110 ±65%^{a}	134 ±23%	157 ±77%	71 ±43%
4 - 6	initial	80±0.3	7.4 ±47%	<100	219	1259 ±7%	40370 ±7%	<100	125 ±19%	162 ±63%^{a}	76 ±61%
7 - 9	soils	40 ±0.3	8.6 ±51%	<100	243^a	1269 ±7%	41906 ±7%	<100	127 ±17%	158 ±66%	<100
1_1 - 3_1		(100)	6.1 ±26%	<100	76	1172 ±7%	37236 ±7%	93 ±50%	128 ±13%	175 ±30%	<30
4_1 - 6_1	acid	(50)	4.1 ±49%	<100	126	1147 ±6%	36503 ±6%	91 ±51%	125 ±10%	155 ±28%	<41
7_1 - 9_1	extracts	(25)	4.9 ±51%	<100	117	1126 ±6%	35487 ±6%	80 ±53%	129 ±10%	145 ±27%	<60
1_2 - 3_2	extracts	(100)	5.5 ±16%	50 ±20%	79	61 ±5%	1886 ±3%	80 ±17%	122 ±4%	123 ±6%	<25
4_2 - 6_2	without	(50)	4.6 ±13%	35 ±18%	119	22 ±5%	769 ±3%	86 ±6%	133 ±3%	130 ±4%	<23
7_2 - 9_2	Cs	(25)	4.6 ±22%	34 ±31%	96	18 ±14%	302 ±3%	78 ±9%	122 ±3%	128 ±3%	<23
1_3 - 3_3	residue	122.8 ±0.6	<1.2	34.9^a	45	15 ±8%	461 ±6%	<6	<2	<3	76 ±47%
4_3 - 6_3	(mainly	66.7 ±0.6	<1.1	22 ±55%	25^a	14 ±17%	426 ±6%	<7	<2	<5	60 ±43%
7_3 - 9_3	SiO_2)	32.7 ±0.4	<1.0	<18	24	23 ±14%	700 ±6%	<8	<2	<3	68 ±24%

^{a} Marked data means that peak of correspondent radionuclide for one or two replicates has non-standard shape or uncertainty of its area determination exceeds allowable limit.

< Denotes evaluation of the possible upper activity level of correspondent radionuclide for samples with activity level less than minimal detectable activity of the radionuclide in the conditions of spectrum recording.

Uncertainties shown in this table correspond to evaluation of an overall method average determination accuracy derived from the results of three replicate analyses.

From represented data it may be concluded, that americium, as well as rare earth radionuclides, are practically completely extracted into solution at acid processing of sample, i.e. the uncertainty of sample composition change for ^{241}Am due to sample dissolution does not exceed 4% (the evaluation is based on the estimated Am activity in residue). Like Am, the reliability and accuracy of the determination of radionuclides Co, Ce and Eu is also increased. Cesium (except the losses at ashing) is also practically whole extracted into solution. Besides cesium, loss at ashing are observed also for ^{125}Sb and the pair ^{106}Ru/Rh. It is interesting to note, that practically whole potassium remains in the insoluble residue, that probably points on its very strong fixing (incorporation into mineral structures) by a clay fraction of soil.

To illustrate the applicability of the method to the real exclusion zone samples and to evaluate its sensitivity, the results of the analyses for a forest soil and a litter samples are given. The uncertainties indicated in the Tab. II and Tab. III are applicable to evaluations of the ^{241}Am activity measurement method accuracy, instead of the overall determination method, which obviously are higher.

As it follows from the data presented in Tab. II, the offered method is suitable for ^{241}Am determination in majority of exclusion zone samples (down to activities of 0.1 - 0.2 Bq/sample).

Table II.
Results of the ^{241}Am determination in a litter and soil samples taken in vicinity of Kopachi-2 village (7.09.95)

Sample No.	Layer (cm)	^{137}Cs, kBq/kg	Sample, g	^{241}Am, Bq/kg, ± %	$^{241}Am/^{137}Cs$	^{241}Am, Bq/sample, ± %
3581	+ 2 ÷ + 3	33.3	2	154 ± 42	0.005	0.31 ± 42
3582	+ 1 ÷ + 2	220.5	2	1404 ± 9	0.007	2.81 ± 9
3583	0 ÷ + 1	235.5	2	2975 ± 9	0.012	5.95 ± 9
3584	0 ÷ - 1	37.5	4	374 ± 9	0.010	1.50 ± 9
3585	- 1 ÷ - 2	7.3	4	66 ± 47	0.009	0.26 ± 47
3587	- 3 ÷ - 4	0.8	4	165 ± 10	0.213	0.66 ± 10
3591	- 15 ÷ - 20	0.04	4	33 ± 27	0.833	0.13 ± 27

Note: Zero mark of depth denotes the border between litter and a podsolic sandy soil For a comparison, in the soil sample taken at the vicinity of Belaya Soroka village, the average of a 9 determinations ratio is $^{241}Am/^{137}Cs = 0.003 \pm 5$ % (Tab. I)

The main uncertainty in majority of the exclusion zone samples analysis results, in our opinion, is introduced yet at the sample preparation stage on division of initial sample and taking of a small analytical weights, but not on the following chemical treatment or measurement stages, because necessary sample composition uniformity cannot be reached by the usual sample treatment methods (without application of the expensive ultra thin sample grinding).

The shown results once again certify for the benefit of our conclusion on the necessity of a large samples dissolution as one of the most expedient method of its homogenization.

To outline the significance of sample composition homogeneity and sample division correctness we can reference on the parallel determinations results shown in Tab. III. The results correspond to different weights of the mechanically averaged, whereas not finely grinded sample containing hot particles. In this case, the ^{137}Cs contents was determined in the greater sample weight of 40÷45 g, then this weight was divided into two parallel smaller weights for ^{241}Am determination. More than the double difference of the obtained ^{241}Am activity for parallel weights of the sample No. 3094 definitely points on the presence of a rather large hot particle in its initial composition.

Finally, it must be notified that the solution remaining after ^{241}Am activity measurement can be feasible for plutonium and other transuranium radionuclides content determination (with application of the known separation techniques). As well as strontium content determination can be performed using the separated cesium and strontium fraction if collected.

Table III.
Results of ^{241}Am determination in the top layer of soil and a litter samples, collected 1.11.94 in vicinity of N.- Shepelichi village

Sample No.	Layer, cm	Sample, g	^{137}Cs, kBq/kg	^{241}Am, Bq/kg, ± %	$^{241}Am/^{137}Cs \times 10^3$
3090	+ 2 ÷ + 3	50	7.4	36 ± 18	4.86
3091	+ 1 ÷ + 2	10	100.8	376 ± 4	3.75
		10		398 ± 3	3.97
3092	0 ÷ + 1	10	3270	14264 ± 1	4.36
		10		13078 ± 1	4.00
3093	0 ÷ - 1	10	1040	6677 ± 2	6.42
		10		7384 ± 2	7.10
3094	- 1 ÷ - 2	20	52.0	244 ± 7	4.69
		20		104 ± 4	2.00

4 CONCLUSIONS

The developed express method of the ^{241}Am contents determination is well suitable, both on sensitivity and on achievable accuracy, for the analysis of a prevailing part of the soil samples and other environmental objects from the exclusion zone

Acid leaching of the quite representative (large) sample weights permits to avoid errors, caused by sample composition inhomogeneity due to presence of hot particles both on sample treatment and measurement stages

Due to shortening of the required number of chemical separation steps (compared to classical procedures), and also in assumption that proposed one step separation proceeds quantitatively, it can be stated that both americium losses during chemical separation and overall determination uncertainty for the offered method are minimal

Implementing the sample acid extract concentration, the ^{241}Am minimal detectable activity down to 0 5 Bq/kg can be achieved for the most common HPGe detector type

The proposed express method is feasible for development of the all most critical radionuclides (Cs, Sr, Am and Pu) analysis method from the same sample weight

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XA9745855

LONG-TERM TREND OF RADIOACTIVE CONTAMINATION OF FOOD PRODUCTS IN BULGARIA AFTER THE CHERNOBYL ACCIDENT

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МНОГОГОДИШНЫЙ ТРЕНД РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ ПИЩЕВЫХ ПРОДУКТАХ В БОЛГАРИИ ПОСЛЕ ЧЕРНОБИЛЬСКОЙ АВАРИИ

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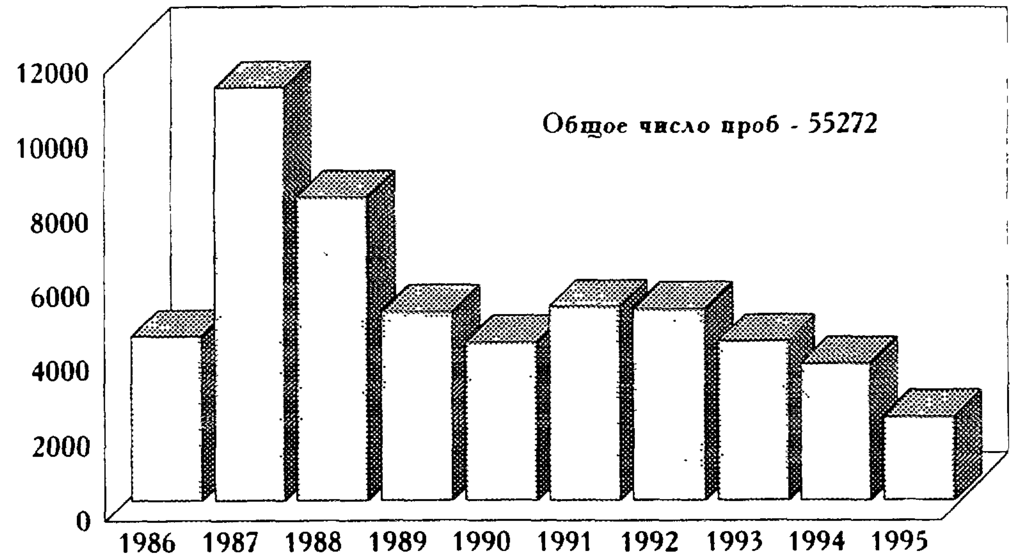
Results which characterize the dinamics for the power of radioactive contamination of foods in the Bulgaria with Cesium radionuclids from May 1986 to December 1995 are presented It was done for motivation of some conclusions during the progress of radiation situation in Bulgaria after the Chernobil accident The data are compared with Maximum residues limits (MRL) of our country as well as that of international organizations They are compared with the background contamination of foods descended from regions affected after experimental nuclear explosion till 1963 too

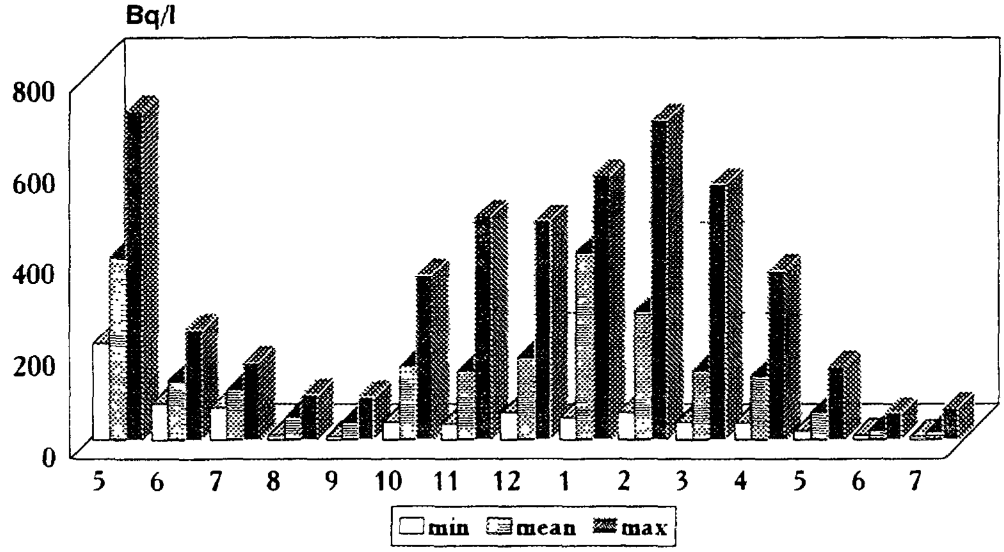
С цели мотивации некоторых констатации и выводы представляется извлечение данн /общий брой 55272/ для периода 1986-1995 г, демонстрирующее на фоне минимальных и средных стоимостей степень загрязнения с цезиевыми радионуклидами основными пищевыми продуктами самым высоким /максимальным и "пиковым"/ после "феномa" Чернобилья в Болгарии [1,2] (фиг 1) Презумция этого обстоятельства является то, что где-то и когда-то было возможно консумирование таких продуктов не подвергнатые радиационного контроля

Среднеарифметические стоимости содержания $^{134}Cs + ^{137}Cs$ в молоке коровь Южней Болгарии с 400 Bq/l в майе 1986 г (среднемаксимальный 720 Bq/l) упали на 50 Bq/l в сентебре После того в рамках "второго радиационного пика" эти стойности повысились вновь до 400 Bq/l (690 Bq/l) при самой высокой стоимости выражающийся на 1231 Bq/l (фиг 2) Такога является картина и при мясом (фиг 3) Самыми высокими результатоми получены при бараниной - среднеарифметические стоимости повисились с мая 1986 г (150-201 Bq/kg) до июня (241-824 Bq/kg) и потом уменшились до ноембре (53-152 Bq/kg) С начале 1987 г начинается поднятие до априле (400 Bq/kg), после которого следует понижение до ноембре (11-43 Bq/kg) При начальным загрязнением среднемаксимальные стоимости для Южней Болгарией не превысили 900 Bq/kg, а при вторичным - достигли 2600 Bq/kg при "пиковой" стоимости 7200 Bq/kg

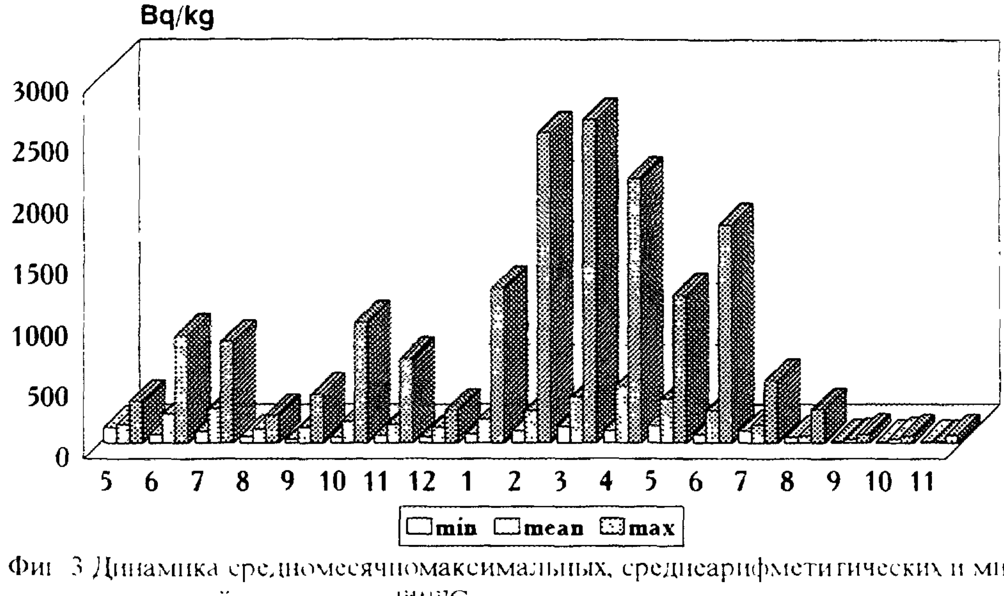
Пшеничное зерно, урожай 1986 г, было загрязнено как следует: в Северной Болгарии (96±44 Bq/kg) и в Южной Болгарии (330±101 Bq/kg) при максимальным содержанием 510 Bq/kg



Фиг. 1 Число проб подвернуты анализом для периоду 1986-1995 г



Фиг 2 Месячная динамика содержании цезиевых радионуклидов в молоке коровь Южней Болгарии



Фиг 3 Динамика среднемесячномаксимальных, среднеарифметических и минимальных стоимостей содержания $^{134+137}Cs$ в мясе мелкого скота

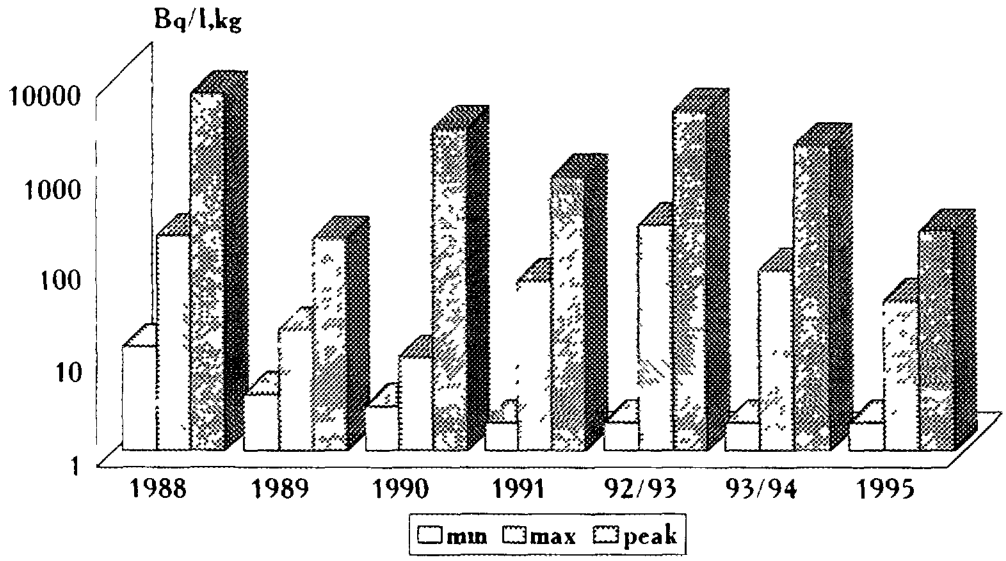
Остальные пищевые продукты были относительно меньше загрязнены: молочные продукты - максимально 799 Bq/kg, пищи для детей - 112 Bq/kg, остальные - до 69 Bq/kg, а лекарственные растение показали активность, достигающая до 40200 Bq/kg

Сопоставляя представленых данных со стоимостях предельнодопустимых норм, принятых тогда как в Болгарии (14 05 1986 г - 370-740 Bq/l,kg, 29 04 1987 г - 75-600 Bq/l,kg) [1], так и международными организациями (370-600 Bq/l,kg) [3] видно, что с одной стороный в определенных периодах времени для некоторых пищ и в некоторых районах было необходимо принят радиозащитных мерок с цели уменьшения допольнителного лучевого нагружения населении, а с другой - определенная часть некоторых пищ необходимо было отклонять с реализиции стокового фонда населения и с экспорта [1] Например во время "второго радиационного пика" весны 1987 г 15-50 % молоком коровь Южней Болгарии не следовало консумироват, а за периоде майя 1987-июня 1987 г 22 % из партид мяса попали под радиоционно-гигиенного запрящения

Сравнивая степень загрязнения с цезиевых радионуклидов с обще фолаутного из ядерных взрывов до 1963 г, например при пшенице и ее продукты помола, получилось, что она на 75 раз больше Содержания этих двух радионуклидов в молоке, мясе и пшенице в стороны из затронутого региона /Австрия, Венгрия, Германия и Греция/, было как следует с 2 3-7 0, 1 3-4 6 и 2 2-8 0 раза меньше тем в Болгарии Это можно использовать как объяснение факта, что несмотря на того, что по сумарного откладывания ^{131}J и ^{134}Cs + ^{137}Cs Болгария находится на восьмом месте среди европейских стран, она занимает первое место по инкорпорацией в организме ^{131}J у детей и цезиевых радионуклидов у взрослого населения [4] К этим надо добавить и то, что, несмотря на мальенких и болших пропусках и недосматриваниях, не было соблюдено и приложение принципа "ALARA"

После майя 1987 г началось относительно быстрое уменьшение содержания цезиевых радионуклидов в молоке на 10 Bq/l и в мясе до 45 Bq/kg (к ноембре того же года) Осредненые стоимости для целой стороне о наличие ^{134}Cs + ^{137}Cs в пшеничном зерне, урожай 1987 г (8 8 ± 3 0 Bq/kg) показали на 26 раз уменьшение по сравнению с 1986 г (230 ±142 Bq/kg)

При определенных пищевых источниках Чернобилское загрязнение однако оказалось прочно [2] (фиг 4) "Пиковые" стоимости являются эти на многолетных лекарственных растении, сухим



Фиг 4 Содержание цезиевых радионуклидов в пищи с 1988 по 1995 г

грибом и бараниной. Минимальные стоимости (2-13 Bq/l,kg), которые встречаются часче, показывают отзвучание события Максимальные (5-278 Bq/l,kg) - то, что большая част пищи болгаров перетерпела соответное "самоочищение", а "пиковые" (117-7142 Bq/l,kg) - показывают необходимость из перманентного радиационного контроля.

Приведеная информация относится к радиационному статусу и его динамику за периоду 1986 - 1995 г.. Она дает возможность сделать констатацию, что сегодня как основные 15 пищевых продуктов и остальные продукты из "продовольственой корзиной", лимитирующие пищевую диету болгаров, можно консумировать [5] Взнос цезиевых радионуклидов с нормальную пищевую диету в организме болгаров понастоящему можно сопоставить с тот-же самой с 1985 г., должимый глобальных радиоактивных отложении после прекращения экспериментальных ядерных взривов

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XA9745856

PROTECTION OF THE PUBLIC IN A RADIOLOGICAL EMERGENCY: INTERNATIONAL RECOMMENDATIONS AND ACTUAL PRACTICE IN THE USSR AND RUSSIA AFTER THE CHERNOBYL ACCIDENT

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1 INTRODUCTION

Whilst the basic principles for protection of the public in a radiological emergency are well discussed and widely accepted, application of these principles in real intervention practices face serious problems Radiological information is most complicated to understand and interpret for decision-makers. The paper deals with some of these points when establishing intervention levels, which need careful attention to reduce misunderstanding in the decision-making process. The points listed below are considered on the basis of analysis of international recommendations (ICRP, IAEA, CEC et al.) as well as experience gained via the post-Chernobyl intervention policy in Russia The latter is briefly summarized here to introduce the following discussion

2 POST-CHERNOBYL INTERVENTION POLICY IN THE USSR AND THE RUSSIAN FEDERATION

Decisions on countermeasures at the early stage following the Chernobyl accident were taken in the USSR and the Union Republics (now memebers of CIS) with *a priori* developed criteria (the USSR Ministry of Public Health, 1983). At further stages the intervention policy was based on developing temporary annual dose limits and temporary permissible levels (TPL) of radionuclides in foodstuffs Starting from the late 80s the actually authorized decisions were made under strong pressure from social, psycological and political factors making ever-increasing unreasonable radiation protection demands, with the result that zones covered by radiation protection and social assistance measures have expanded, giving the public the false impression that the radiation hazard was underestimated in the first months and years following the accident In the Russian Federation the number of residents of the territories involved in the sphere of implementation of radiation protection and social protection measures increased from 88 thousand in 1986 (territories with caesium-137 contamination S > 555 kBq/m^2 where annual dose in excess of 100 mSv was conservatively projected if no countermeasures were undertaken) to 2 7 millions in 1993 (territories with S > 37 kBq/m^2 in line with the legislative definition of contaminated zones in 1991)

The chronological increase in the scale of protective measures in Russia is shown in Fig 1 Once the "iodine" period had ended, in order to protect the population from external and internal radiation from caesium radionuclides, caesium-137 contamination levels were taken as the criterion for dividing territory into predicted levels of radiation among the population In the summer of 1986, the areas where caesium-137 contamination was at or above 15 Ci/km^2 (555 kBq/m^2) were assigned to the strict control zone (SCZ), within which a range of protective measures (some aimed at reducing exposure levels and others of a social nature, including financial compensation) are being carried out As information on contamination levels became more precise, the SCZ was enlarged and the number of people included in it increased slightly from 85 thousand in 1986 to 112 thousand in 1988 In 1989, social protection measures were extended to cover areas in which the radiocaesium content in milk exceeded 370 Bq/L which, depending on soil and agrotechnical conditions, at that time corresponded to contamination levels of between 100 and 600 kBq/m^2 The number of people within the accident zone increased to 360 thousand A Russian Law passed in May 1991 extended the scope of social protection measures related to the consequences of the Chernobyl accident to cover the area in which caesium-137 contamination exceeded 37 kBq/m^2 This decision boosted the corresponding

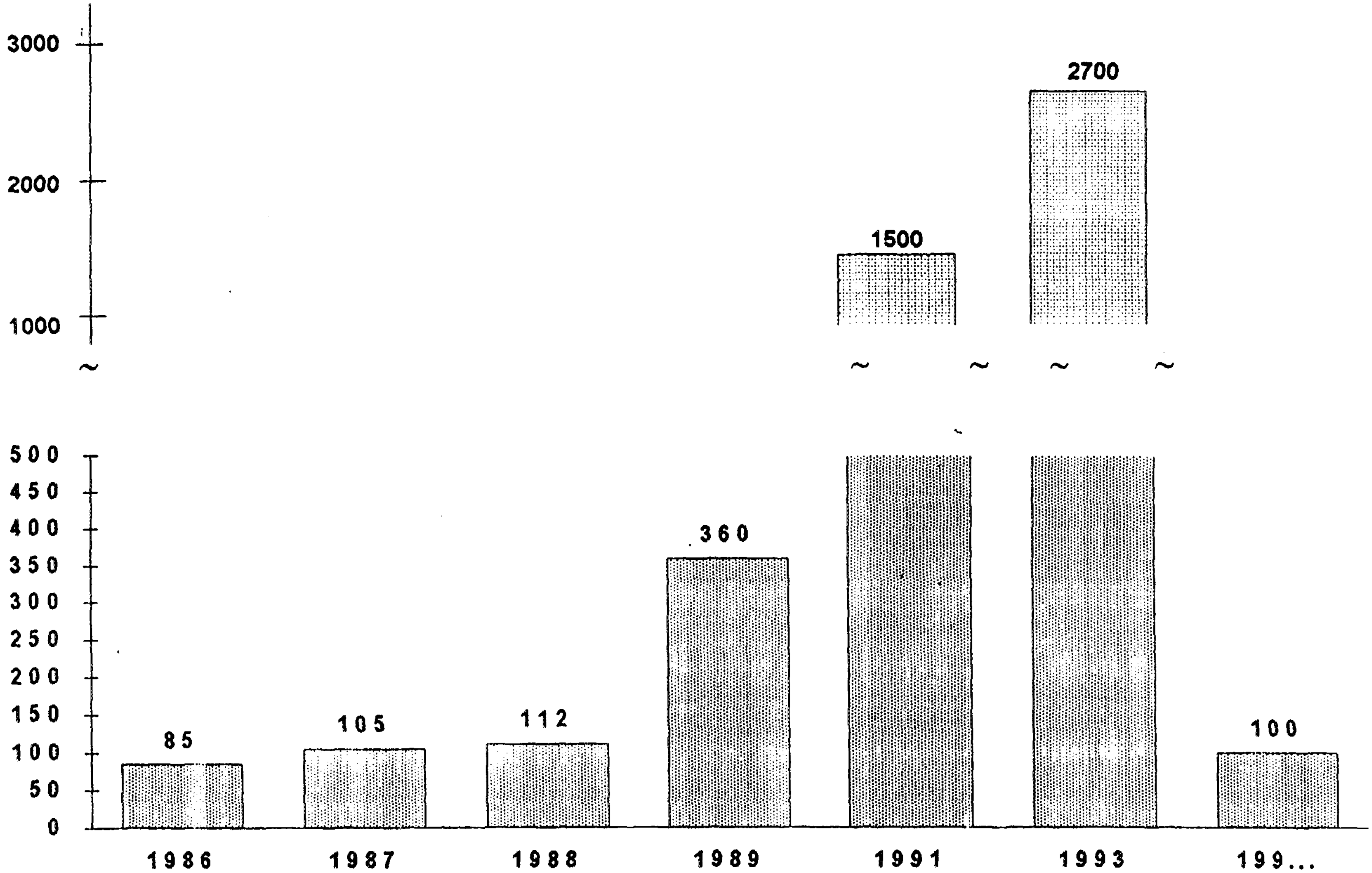

Figure 1. Scope of radiation and social protection measures in the Russian Federation
Number of people in the areas officially involved into protective measures (thousands)

population to 1.5 million. Then, after searching for new areas with S > 37 kBq/m^2 this increased to 2.7 million.

A paradoxical phenomenon has arisen in which, instead of changing over to the recovery stage following the accident, the scale of intervention is increasing. This phenomenon was a result of both current socio-political processes in the USSR/CIS/Russia and lack of a methodology for decision-making at the late stages of an accident situation when return by the public to a normal living routine in areas affected by radioactive contamination is needed. This need has led in later years to the development of a concept for rehabilitation of territories affected by radioactive contamination. The aim of this concept is to optimize the area of social protection measures and the number of people involved in social attention related to the Chernobyl accident in line with actual radiological grounds and available resources.

The latest concept (adopted officially in July 1995) suggests social protection to be limited by those areas where the current annual effective dose assigned to Chernobyl accident exceeds 1 mSv in the absence of countermeasures. Our rough assessment gives the number of those people about one hundred thousand. It means that 96% of 2.7 million of people currently assigned as living in the contaminated zone will be deprived of existing privileges (benefits and compensations). A negative response of both local authorities and the population may be anticipated, and one might not definitely designate a date (year) of putting the concept into real practice.

3. SOME POINTS FOR DISCUSSION AND FURTHER DEVELOPMENTS

It is well known and now described in publications that the situation shown on Figure 1 and the evolution in Table 1 are the result of public pressure on decision-makers, leading to a situation where radiological considerations are dominated by sociopolitical factors. To a considerable extent it was associated with the specific historical circumstances in the USSR and Russia during the years after the accident. However, the conflict between radiological principles for and practical implementation of protective measures in the event of major radiation accidents is, to a certain extent, a universal one. In other words, this controversy might arise again in the case of a major accident in another country with a more favourable (than in the USSR/CIS/Russia) social atmosphere. Several points are discussed below in the light of the search for possible ways to reduce a controversy between the theory and practice of intervention.

3.1. Projected, avertable and residual dose

Conceptual evolution of an intervention policy in the USSR and Russia was determined by both time course of radiological situation and sociopolitical influences. Cost-benefit analysis or other analytical approximations to take account of avertable dose were the subject of some scientific studies, but those were not used as a basis for decisions. The last column of Table 1 shows the meaning of numerical levels of dose at various stages of decision making (while the terms 'projected' or 'residual' were not used in the wordings of documents). Projected and residual doses might be derived from avertable doses by calculation of the suggested half-life of the source of radiation. But actually numerical levels of doses in all stages shown in Table 1 were justified mainly by their setting between dose limit for normal practices and dose levels related to deterministic effects. What about *residual* dose, it may be interpreted in terms of *residual risk*. The latter may facilitate a positive public perception of real radiological risk by comparing residual risk with other risks of day-to-day life. Projected dose as a surrogate of avertable dose is more practicable to use for urgent decisions on short-term countermeasures at the early stage of an accident (sheltering, iodine prophylaxis, evacuation). Thus, in spite of the fundamental role of avertable dose in intervention philosophy, projected and residual doses seem to be more practicable for both calculations and public perception.

Table 1

Stages of the intervention policy in the USSR and the Russian Federation after the Chernobyl accident

Concept	Application period	Interpretation of dose level
Decision making criteria (1970-1983)	April-May 1986	Short term projected dose
Temporary permissible levels (annual dose limits and DILs in foodstuffs)	1986-1989	Annual residual dose
Lifetime dose concept (350 Sv)	1990	Residual dose to time of decision making plus projected dose for further years
Current official concept (1-5 mSv)	1991 - ...?.	Annual residual dose
A concept of radiation, health and social protection and rehabilitation of population of the Russian Federation, suffered from emergency radiation exposure (1995)	199...?	Annual projected dose

Table 2

INTERVENTION LEVELS FOR CAESIUM-137 IN FOODSTUFFS

International or national guide	Specific activity, Bq/kg			Application
	Baby food	Dairy produce	Other foodstuffs	
USSR, 1986 Temporary permissible levels	-	370	3700	Total beta-activity in food item. Temporary post-Chernobyl levels
CEC, 1989, Council Regulation (Euratom) No.2218/89	400	1000	1250	Maximum permitted levels following a nuclear accident
CEC, 1990 Council Regulation (EEC) No.737/90	370	370	600	Imported food from third countries after the Chernobyl accident
FAO/WHO, 1989 Codex Alimentarius Commission	1000	1000	1000	Non-intervention level for international trade
Russia, 1993 Temporary permissible levels	185	370	600	Sum of caesium-137 and caesium-134
ICRP, 1993 ICRP Publication No.63	1000-10000			Range of optimized values
Russia, 1995 Radiation Safety Standards (draft)	1000-3000			Decision making criteria for the first year after a major nuclear accident

3.2. Optimization, conservatism vs. realism

Practical implementation of the optimization principle presupposes that dose calculations are based not on the critical population group but on an average individual in a population group subjected to intervention in the form of specific protective measures Essentially, taking decisions on an optimization basis should be founded on realistic (i e calculated on average levels) and not pessimistic (i e calculated on the worst levels) forecasts of irradiation levels However, it is very difficult to assess how realistic a forecast is, particularly in the initial phase of an accident, when very little or no dosimetric information on the developing situation in available As dosimetric information is received forecast uncertainty is reduced, but in the initial period it is so great that a significant degree of conservatism in dose forecasting is fully justified, in order to avoid seriously underestimating the potential danger, including that of overexposure This applies particularly to major radiation accidents, which can (in the absence of protective measures) lead to projected doses reaching deterministic effect levels Only when the conservative value of the projected dose can be corrected downwards to a level below that corresponding to deterministic effects (or that triggering compulsory intervention) may any further decisions be made in accordance with the optimization principle A significant degree of conservatism in longer-term dose forecasting can be justified by the inevitable influence of the socio-psychological factor, insofar as it is obviously undesirable to have a situation in which actually recorded radiation indicators exceed forecast values Thus, balancing realistic and conservative approaches should be reasonable for dose assesment in the decision-making process

3.3. International harmonization

The imposing significance of references to international recommendations is weakened by the lack of complete concordance in methodology, intervention level values and interpretation between various international bodies An example of the discrepancy between various international guides is given in Table 2 In 1986 the Group of Experts recommended to CEC 4 kBq/kg for dairy products and 5 kBq/kg for other major foodstuffs (and for the first year following an accident 20 kBq/kg and 30 kBq/kg) But CEC, due to political considerations, reduced the proposed values by a factor of 4 and adopted the levels shown in Table 2 as maximum permittable levels following a nuclear accident For the actual post-Chernobyl situation, even more restrictive values were authorized for radiocaesium in food products imported to EC countries 370 Bq/kg for diary products and infant food, 600 Bq/kg for other food products These values conflict with CAC document where higher values are considered actually as non-intervention levels ("These CAC guideline values are not intervention levels but rather non-intervention levels, as it is illogical to place local restriction on foodstuffs acceptable for international trade" [ICRP Publication 63, paragraph 92]) In view of the general current trend to "overprotection" in Russia, the most restrictive values from international recommendations were adopted in the last version of the temporary permissible levels (TPL-93) More optimized values for the first year after a major nuclear accident are established in new Russian Radiation Safety Standards (RSS-96)

Comparison similar to that in Table 2 might be applied to intervention levels for other paths of exposure The application of different intervention levels in similar circumstances would cause much confusion in the public mind and among authorities responsible for decision making Thus, there is a need for further international harmonization of intervention levels

4 CONCLUSION

The Chernobyl accident stimulated the most competent international bodies to further development of conceptual and methodological grounds for protection of the public in major radiation accidents This development resulted in the new documents of the International Commission on

Radiological Protection (Publication 63), the International Atomic Energy Agency (Safety Series No 109) and from other organizations

Nevertheless, many problems still arise in the practical application of intervention principles The main problem is the controversy between conceptual grounds of radiological emergency response and the practice of decision-making under the inevitable pressures of sociopolitical factors and inadequate public perception of radiation risk This paper dealt with some disputable points for establishing intervention levels Many other considerations are emerging from the continuing debate on lessons learned from the Chernobyl accident, other major precedents as well as from experience in the areas of nuclear emergency planning and preparedness It means a need for further development of intervention methodology in radiation protection

SPECIALIZED ECOLOGICAL FORESTRY SYSTEM FOR THE MANAGEMENT OF FORESTS IN THE CHERNOBYL EXCLUSION ZONE

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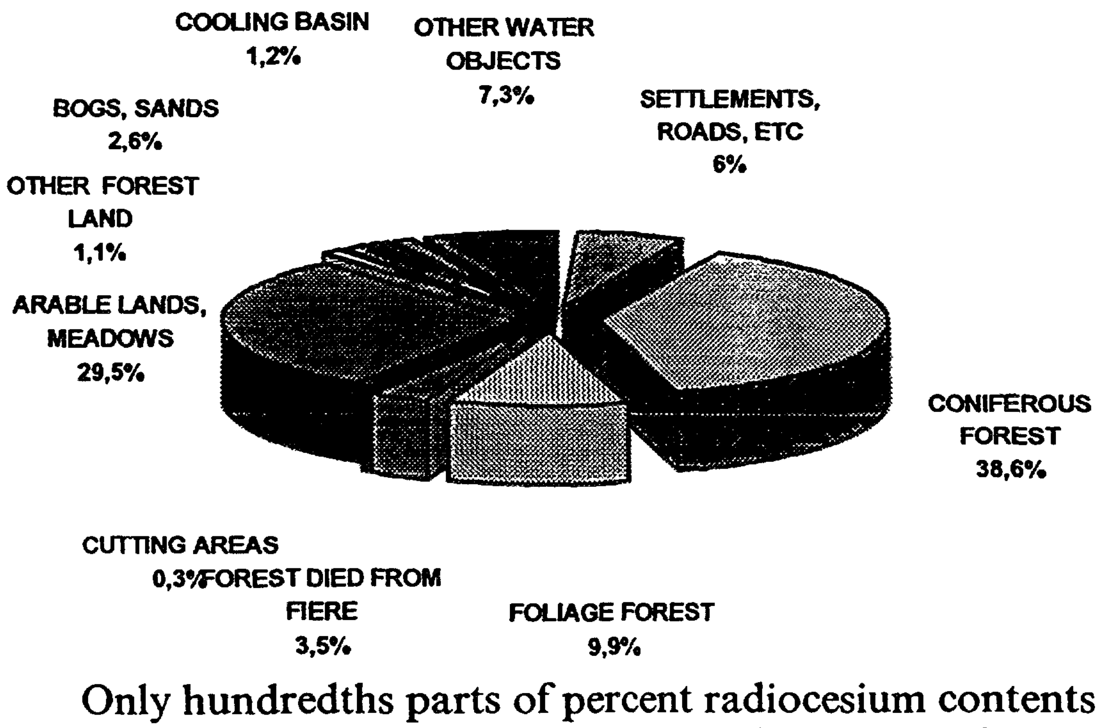
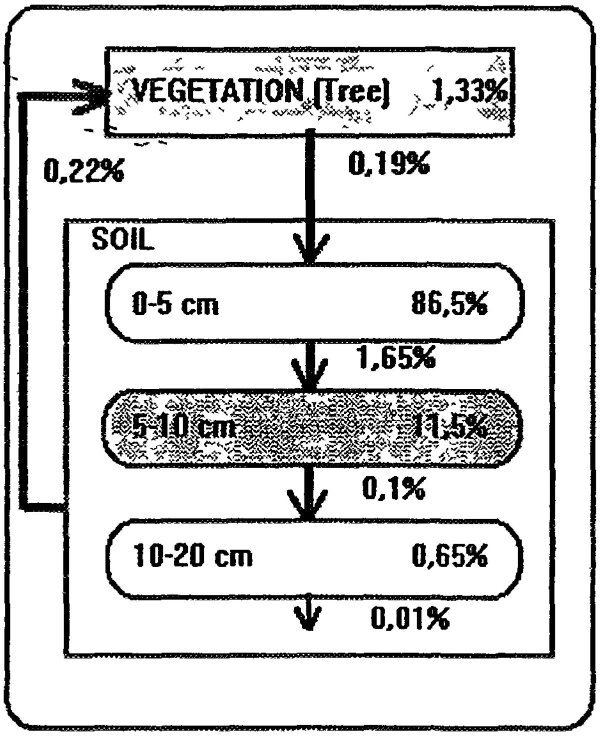
Prevention of radionuclides expansion in environment is one of the most complicated tasks in the complex of problems connected with measures, to decrease consequences of accident in Chernobyl nuclear power plant. Ten years experience of work in the exclusion zone show that the most real biogeochemical barrier on the way of radionuclides transfer are forests, which occupy half of the territory and keep main part of falls in the boundaries of forest landscapes.

STRUCTURE OF LAND CLASSIFICATION IN EXCLUSION ZONE OF CHNPP IN 1995 YEAR

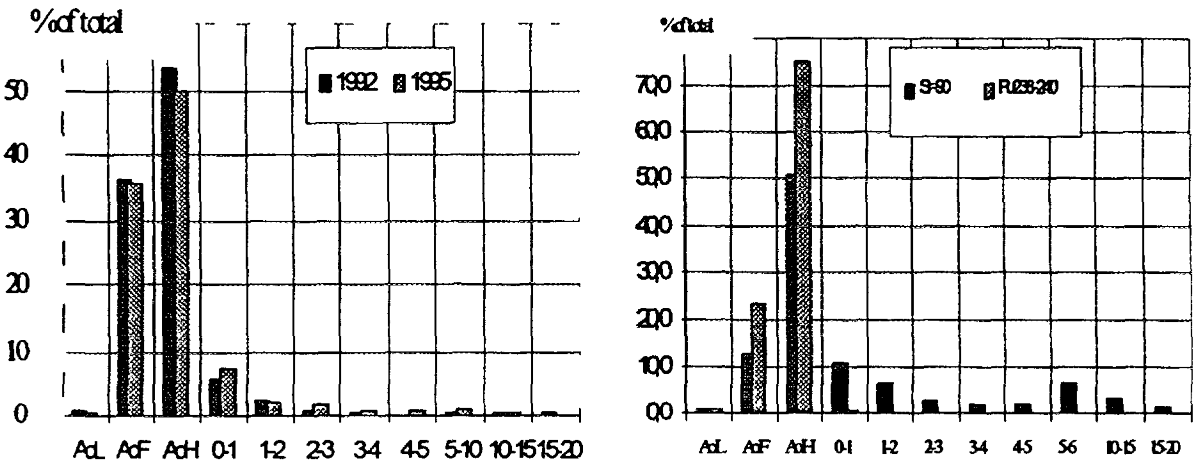


Only hundredths parts of percent radiocesium contents are transfered out of boundaries of normally functioning forest ecosystem. Amount of radiocesium coming in surface of forest litter with the falling leaves and in another ways is equal to amount absorbed by plants annually.



Picture 1. Diagram of ^{137}Cs distribution in pine forest.

The main part of radionuclides are now in the forest litter.



^{137}Cs, (1992, 1995) ^{90}Sr, $^{238-240}Pu$, (1995)

Picture 2. Distribution radionuclides through the soil profile of typical pine stand (% of total amount in soil)

Radionuclides migrations forecasts models show that with natural flow of processes in the nearest 10-15 years character of radioactivity distribution in forest ecosystems will not be changed sufficiently.

Cs-137 distribution forecast in soil profile (% to volume)

Layer	1993	1998	2003
Litter Ao	78.6	66.1	55.6
Soil0-5 sm	20.4	32.8	42.0
5-10 sm	0.8	1.1	1.8
10-15 sm	0.2	0.4	0.6

Violations caused by impossibility to conduct normal forestry and natural disasters leads to migration processes speed increase. After the high forest fire the main part of radionuclides that would stay there during 15-20 years moves to mineral part of the soil.

Distribution of ^{137}Cs after forest fire

Type of fire	burn down of litter, %	Distribution of radioactivity,%	
		Litter	Soill
Control	0	60 - 80	20 - 40
Low fire	10 - 30	60 - 70	30 - 40
Transitional	30 - 40	40 - 50	50 - 60
Crown fire	45 - 80	20 - 40	60 - 80

Similar situation takes place in case of full destruction of forest stand caused by another reasons.

The forests death in exclusion zone have significant scale: aproximately 1500 ha of so-colled ``red forest" died during the first years after disaster as result of irradiation of trees in letal doses affect; more than 17 thousand ha of forests were demaged by forest fires (including 4.2 thousand ha of crown forest fires); near 2 thouthand ha died as result of growing up of underground water.There are any different causes leading to increase of forestand deadth. Those are forest fire, growing up of vermin and illness and rising up of undergrouund water lever as a result of meliorational systems disregulation.

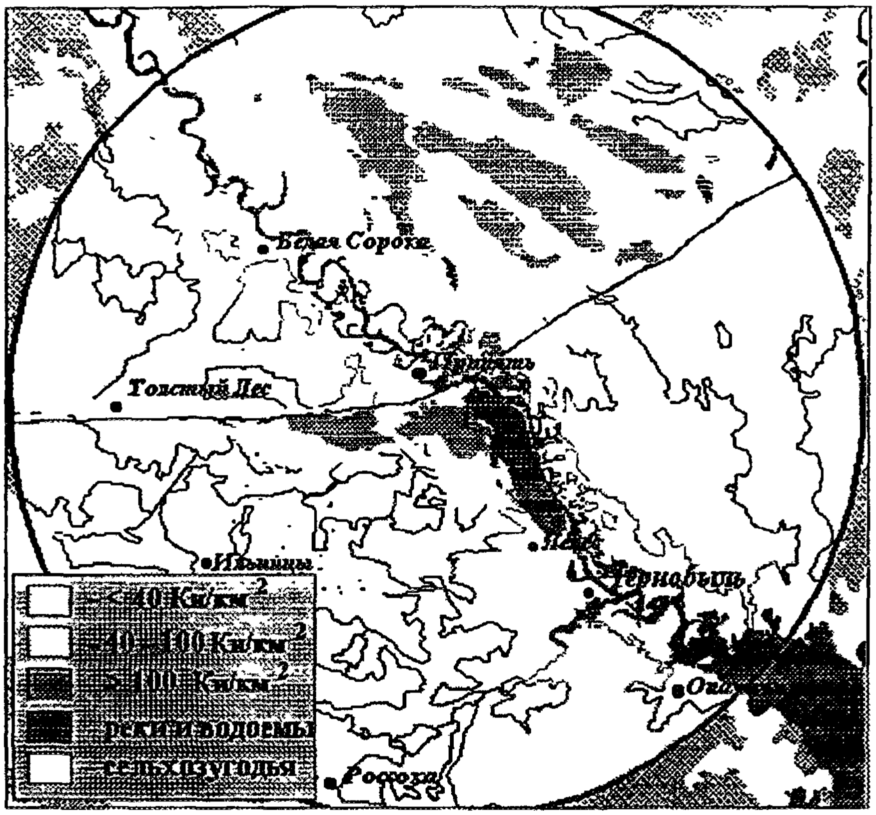
Reasons of forests damage and death in exclusion zone.

Factors	Areas, thous.ha
Radiation injury	1.5
Forest fire total	17
- crown fire	4.2
Growing up of underground water.	2
Windfell and stormfell in forest	0.5% total stock
Vermin and illness in forest	0.2% total stock

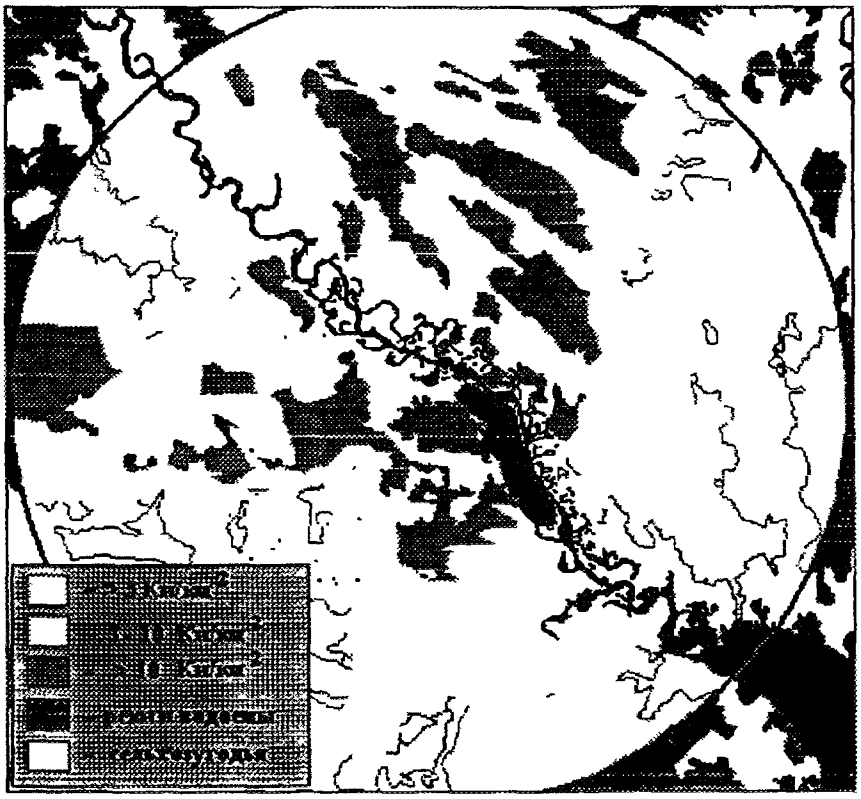
Stabilization of situation requires:

- conservation of existing forest stands ability to survive by restoration of forestry masures system;
- creation of protecting forest stands solid system in the sites with high pollution density;

Specialised forestry enterprise ``Chernobylles" created in 1992 secure fulfillment of these tasks. The basis for planning and carrying out of tasks is territory division by the pollution levels.



Schematical Map of forestand contamination by ^{137}Cs



Schematical Map of forestand contamination by ^{90}Sr

There were separated 3 districts with corresponding regimes of forestry:

- district under control of carrying out of specialized forestry, pollution densities: $^{137}Cs < 40$ Ci/km^2, $^{90}Sr < 3$ Ci/km^2,
- $^{239}Pu < 0.1$ Ci/km^2;
- district of limited carrying out of specialized forestry, pollution densities: ^{137}Cs 40-100 Ci/km^2, ^{90}Sr 3-10 Ci/km^2, ^{239}Pu 0.1-0.3 Ci/km^2;
- district of restricted (reservational) regime, pollution densities: $^{137}Cs > 100$ Ci/km^2, $^{90}Sr > 10$ Ci/km^2, $^{239}Pu > 0.3$ Ci/km^2.

Grouping of forests of 30-km exlusion zone according with forestry carrying out regime.

Regime of forestry	^{90}Sr		^{137}Cs	
	Density of contamination, Ci/sq.km	Area, % observed	Density of contamination, Ci/sq.km	Area, % observed
control of carrying out of specialized forestry	3	34	40	78
limited carrying out of specialized forestry	3 – 10	34	40 –100	8
restricted (reservational) regime	>10	32	>100	14

PROBLEMS OF DETERMINING THE TRUE GENETIC SITUATION IN THE CHERNOBYL NUCLEAR POWER PLANT EXCLUSION ZONE

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XA9745858

ПРОБЛЕМЫ ОЦЕНКИ РЕАЛЬНОЙ ГЕНЕТИЧЕСКОЙ СИТУАЦИИ В ЗОНЕ ОТЧУЖДЕНИЯ ЧЕРНОБЫЛЬСКОЙ АЭС

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30 километровая зона отчуждения Чернобыльской АЭС представляет собой уникальный в мировом масштабе полигон для разворачивания исследований генетических последствий в экосистемах, вызываемых экологическими стрессами. Она является огромной моделью существенного изменения комплекса экологических факторов, на фоне которого воспроизводятся представители всех таксономических групп живых организмов. Неравномерность экологических изменений внутри зоны создает возможность сравнительного изучения последствий таких изменений при их разной интенсивности. Широкое видовое разнообразие живых организмов, населяющих зону, позволяет исследовать видоспецифические черты ответа генофондов на условия экологических стрессов. Сохранение в этой зоне экспериментальных ферм и возделываемых полей для воспроизводства представителей сельскохозяйственных видов животных и растений, специальных вивариев для лабораторных животных создает уникальную возможность изучения особенностей влияния экологических катастроф на виды, воспроизводящиеся в искусственных условиях, создаваемых человеком.

Частью генетических исследований, выполняемых в зоне отчуждения в последние 10 лет является анализ генетической структуры группы крупного рогатого скота, воспроизводящегося в условиях хозяйства "Ново-Шепеличи" (Припять, 10 километровая зона Чернобыльской АЭС), а также линейных лабораторных мышей, размножающихся в спецвиварии в 30 километровой зоне Чернобыльской АЭС (созданном Институтом молекулярной биологии и генетики Украинской НАН). Выбор модельных обектов для исследований был обусловлен несколькими обстоятельствами. Основными основателями экспериментального стада крупного рогатого скота являются три коровы и бык, пережившие катастрофу 1986 года. Это стадо представляет собой генетически гетерогенную группу животных, позволяющую с использованием молекулярно-генетических маркеров вести поиск новых мутаций структурных генов и изучать динамику генофонда исходных животных в поколениях, воспроизводящихся в уникальных экологических условиях. Линейные мыши обеспечивают возможность анализа закономерностей возникновения повреждений хромосомного аппарата в генетически гомогенной группе организмов в зависимости от их возраста, сезона исследования, принадлежности к различным поколениям, родившимся после завоза основателей экспериментальной популяции мышей в условия спецвивария Следует отметить также сходство хромосомного аппарата мышей и крупного рогатого скота - в кариотипах обоих видов аутосомы представлены только акроцентрическими (одноплечими) хромосомами, наиболее распространенным вариантом хромосомных мутаций для обоих видов являются робертсоновские транслокации. Кроме того, оба модельных объекта не зависят от изменений межвидовых взаимоотношений, поскольку воспроизводятся в искусственной среде, создаваемой человеком.

Среди исследованных животных не выявлено наличие новых аллельных вариантов по 18 локусам различных генетико-биохимических систем, не обнаружено также носителей конститутивных цитогенетических аномалий (в частности, робертсоновских транслокаций). Это, по нашему мнению, свидетельствует о том, что комплекс специфических условий разведения животных в зоне отчуждения Чернобыльской АЭС и, в частности, воздействия хронического низкодозового ионизирующего облучения не являются высокоактивными индукторами мутаций структурных генов. Обнаружено заметное увеличение частоты хромосомных аберраций в клетках крови крупного рогатого скота и в клетках костного мозга линейных мышей (линия CC57W/Me). Однако это увеличение выявлялось на фоне уменьшения пролиферативной активности клеток и увеличения продолжительности клеточного деления (отношение числа двухядерных лимфоцитов к числу метафаз в 1000 клеток). В контрольной группе мышей также наблюдали существенное увеличение частоты встречаемости хромосомных аберраций с возрастом (у старых мышей в возрасте 16-18 месяцев) на фоне снижения пролиферативной активности. У группы старых мышей в экспериментальных условиях Чернобыльской зоны частота встречаемости хромосомных аберраций существенно ниже, чем в контроле и выше частота и скорость клеточных делений. Это позволяет сделать вывод о том, что частота встречаемости хромосомных аберраций является сложным признаком, тесно связанным с такой широко варьирующей физиологической характеристикой, как интенсивность клеточного обновления различных тканей, что затрудняет его использование в целях прогноза реальных генетических последствий воздействий экологического стресса.

Экспериментальная группа черно-пестрого скота отличалась от контрольных групп той же породы распределением аллельных частот, сниженной экспрессией отдельных биохимических маркеров, по некоторым локусам - нарушением равновесного распределения генотипов. По генетической структуре по локусу трансферрина опытная группа отличалась от контрольных отсутствием редкого аллельного варианта TfE, сниженной частотой встречаемости аллельного варианта TfD1 и повышенной - TfD2 Следует отметить, что относительно пониженная частота встречаемости аллельного варианта TfD2 является породной характеристикой черно-пестрого скота Прямой семейный анализ показал, что в первом поколении животных, полученных от трех коров и быка, переживших Чернобыльскую катастрофу, наблюдается выраженное нарушение равновероятной передачи потомству аллельных вариантов по двум локусам - трансферрину и церулоплазмину. Выявленное существенное увеличение частоты встречаемости асинхронности расщепления центромерных районов хромосом, а также двухядерных лимфоцитов в клетках периферической крови крупного рогатого скота в зоне отчуждения Чернобыльской АЭС свидетельствуют о нарушении у них процессов клеточного деления. Можно ожидать, что наблюдаемый сдвиг генетической структуры у опытной группы черно-пестрого скота от типичного для породы связан с дисфункцией механизмов клеточного деления и ранней гибелью эмбрионов-носителей элиминирующихся аллельных вариантов.

Исследования генетической изменчивости в зоне отчуждения Чернобыльской АЭС, выполняемые в течение 10 лет на различных диких и сельскохозяйственных видах растений и животных позволили получить похожие результаты.

Как правило, у исследованных объектов наблюдаются выраженные фенотипические изменения со стороны различных физиологических систем, в частности, у животных - иммунной системы, выявлены также изменения генной экспрессии, например, изменения органоспецифичного изоферментного спектра у отдельных сельскохозяйственных видов в некоторых органах. Однако анализ собственно генетических последствий Чернобыльской катастрофы показал довольно сложную картину.

С одной стороны, у многих видов наблюдается увеличение частоты встречаемости цитогенетических аномалий, в частности, хромосомных аберраций в популяциях соматических и генеративных клеток целых организмов. С другой - до сих пор не удалось выявить увеличения количества носителей конститутивных (наследуемых) цитогенетических аномалий у представителей различных видов, размножающихся в зоне отчуждения в сравнении с группами организмов, находящихся в более благоприятных условиях Это относится и к сельскохозяйственным видам, и к лабораторным животным, а также к представителям дикой фауны

Увеличение частоты встречаемости хромосомных аберраций не сопровождалось появлением и новых аллельных вариантов по ряду исследованных структурных генов ядерного генома у различных видов растений и животных Таким образом, наблюдается очевидное противоречие между наличием признаков, традиционно связываемых с мутационным процессом - увеличение размаха фенотипической изменчивости, хромосомных аберраций - и отсутствием четко документированного факта фиксации новых мутаций в виде организмов, несущих конститутивные цитогенетические аномалии, новые аллельные варианты структурных генов

Получены предварительные данные, позволяющие предполагать уменьшение влияния экологического стресса на прередачу аллельных вариантов в последующих поколениях - восстановление со временем равной вероятности их наследования. Однако в настоящее время степень изменений генофондов сельскохозяйственных видов и динамика таких изменений в поколениях находится в процессе исследования. Важно подчеркнуть, что радиорезистентность живых организмов является полигенным признаком и имеет широкую внутривидовую изменчивость, а радионуклидное загрязнение является только одним из факторов изменений условий воспроизводства различных видов в зоне отчуждения Чернобыльской АЭС. В этой связи практически невозможно моделирование и исследование генетических эффектов Чернобыльской катастрофы в лабораторных условиях, изучение дозовых зависимостей, поскольку генотоксичность одних и тех же доз ионизирующего облучения разная для разных генотипов, а изменения приспособленности генотипов зависит не только от радионуклидных воздействий, но и от ряда других факторов, в частности, от межвидовых взаимоотношений, антропогенных влияний. Все это позволяет рассматривать зону отчуждения Чернобыльской АЭС как уникальную естественную модель для изучения долговременных генетических последствий экологического стресса.

GENETIC VARIABILITY IN PLANTS AND ANIMALS IN THE 30 KILOMETER ZONE AT THE CHERNOBYL NUCLEAR POWER PLANT

XA9745859

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ГЕНЕТИЧЕСКАЯ ИЗМЕНЧИВОСТЬ РАСТИТЕЛЬНЫХ И ЖИВОТНЫХ ОРГАНИЗМОВ, НАХОДЯЩИХСЯ В 30-км ЗОНЕ ЧЕРНОБЫЛЬСКОЙ АЭС

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Важность исследований генетических последствий в группах растительных и животных организмов, воспроизводящихся в условиях повышенного радионуклидного загрязнения в 30-км зоне Чернобыльской АЭС определяется рядом обстоятельств. Наиболее важным из них с практической точки зрения, очевидно, является необходимость разработки четких, однозначных методов биоиндикации генотоксичных эффектов низкодозовых радионуклидных воздействий и прогноза их отдаленных генетических последствий в популяциях соматических и генеративных клеток организмов различных видов.До сих пор, в большинстве случаев, в качестве биоиндикации генотоксических воздействий используют показатели прямого повреждения молекул ДНК. Однако, как правило, повреждения ДНК в клетках сопровождаются их гибелью, что обуславливает, по-видимому, незначительный вклад грубых повреждений генетического материала в поколения соматических и генеративных клеток. Кроме того, клеточные популяции целого организма отличаются по чувствительности к радионуклидным воздействиям, одна и та же клеточная популяция обладает разной радиочувствительностью в условиях in vivo и in vitro. Не выявлеы наиболее радиочувствительные органы и физиологические системы, изменения функций которых под влиянием радионуклидных воздействий меняют радиопротекторные свойства целого организма. Неоднозначны также данные о наиболее значимых изменениях клеточных органелл для индукции дестабилизации генетического материала. Очевидно, что появление тестируемых мутаций, таких как хромосомные аберрации, новые аллельные варианты, изменения генных доз являются лишь небольшой частью сложной сети событий, связанных с нарушением гомеостатического состояния целого организма и клеточной физиологии. То есть, до сих пор остаются недостаточно изученными "мишени" радионуклидных воздействий на организменном и клеточном уровнях, изменения которых играют ведущую роль в главных негативных эффектах генотоксинов - индукции неоплазий в соматических тканях и генетических дефектов в потомстве.

Следует учитывать, что возникающие внутривидовые изменения могут быть обусловлены не только прямыми генотоксичными воздействиями факторов экологического стресса, но и являться косвенным следствием их действия.

В первом случае возникающие изменения являются следствием непосредственной индукции увеличения мутационных событий в сообществах живых организмов. Однако снижение жизнеспособности носителей мутаций может приводить к отсутствию их заметного вклада в генофонд последующих поколений. Наиболее важным аспектом для реальных генетических последствий экологических катастроф является не собственно появление новых мутантных вариантов, а элиминация из воспроизводящейся группы особей их носителей - вымывание из генофонда вида той его части, которая ассоциирована с носителями повышенной чувствительности к генотоксическим воздействиям. Таким образом, выявляемые мутации, прямо связанные с повреждением генетического материала, важны не сами по себе, а как признак индивидуумов с генетически детерминированной повышенной чувствительностью к генотоксическим воздействиям, количество таких особей - как характеристика популяции (вида), позволяющая прогнозировать степень изменений соответствующего генофонда. То есть для изучения реальных генетических последствий экологических катастроф выявление новых мутаций является не конечным этапом исследования - а только его началом, поскольку далее необходимо выяснить генетически обусловленные причины их возникновения и ассоциированные генные комплексы, уходящие вместе с ними из репродуцирующейся части генофонда.

Внутривидовая гетерогенность по чувствительности к генотоксическим воздействиям известна давно, однако до сих пор ее видоспецифичные генетические основы остаются недостаточно изученными. В то же время очевидно, что возможность долговременных прогнозов генетических последствий экологических катастроф, так же как и разработка методов влияния на них, непосредственно зависит от наличия генетических маркеров чувствительности организмов к их мутагенным эффектам. Выявление таких маркеров может позволить не только планировать и влиять на структуру генофонда популяции определенного вида в зоне экологической катастрофы, но и вести поиск звеньев метаболических сетей общего обмена организма, генетически обусловленная изменчивость которых связана с повышенной чувствительностью к генотоксическим воздействиям с дальнейшей целью разработки методов ее снижения у отдельных индивидуумов.

Во втором случае наблюдаемые изменения могут не являться следствием индукции новых мутаций, а обуславливаться рядом популяционно-генетических причин. Так, со времен исследований И.И. Шмальгаузена хорошо известно, что причиной всплеска фенотипической изменчивости в условиях экологических катастроф могут быть нарушения межгенных взаимодействий, лежащих в основе функциональной интеграции генетического материала в системах целостного организма и, в связи с этим, проявление ранее скрытой генетической изменчивости. Такая фенотипическая изменчивость не обусловлена появлением новых вариантов структурных генов, а связана с новыми условиями функционирования предсуществующего генетического материала в новых условиях среды.

Возникновение новых условий отбора предполагает резкое изменение приспособленности предсуществующих генотипов и, соответственно, их вклада в генофонд последующих поколений. Преимущественное выживание наиболее приспособленных к новым условиям среды может приводить к глубоким изменениям структуры генофондов видов. Катастрофичным, в частности, для межвидовых взаимоотношений, является не только исчезновение вида, но и трансформация его генофонда, при которой генотипы, встречавшиеся ранее с минорной частотой - становятся преобладающими. Именно такие изменения структур генофондов видов, попавших в условия экологических катастроф, могут являться определяющими в дестабилизации предсуществующих экосистем. Очевидно, что без глубокого изучения таких изменений, их видоспецифичности и их механизмов полностью отсутствует реальная возможность разработки каких-либо долгосрочных прогнозов динамики экосистем, испытывающих влияния экологических стрессов и подходов к методам их компенсации.

Таким образом, генетические последствия непосредственного повреждения генетического материала и увеличения фенотипической изменчивости за счет реализации скрытой генетической информации в новых условиях связаны с трансформацией структуры предсуществующего генофонда. Однако направление и механизмы таких последствий в генофондах зависят от причин, их вызывающих. Это обусловливает острую необходимость тщательного выяснения в каждом конкретном случае: является ли выявленное в зоне экологической катастрофы изменение следствием истинного повреждения генетического материала - то есть мутационным событием - или результатом реализации ранее скрытой генетической изменчивости. Решение этого вопроса является принципиальным для разработки реальных долговременных прогнозов изменений экосистем и методов их компенсации в зонах экологических катастроф.

DISPOSAL OF LOW AND MEDIUM LEVEL RADIOACTIVE WASTE IN THE CHERNOBYL EXCLUSION ZONE

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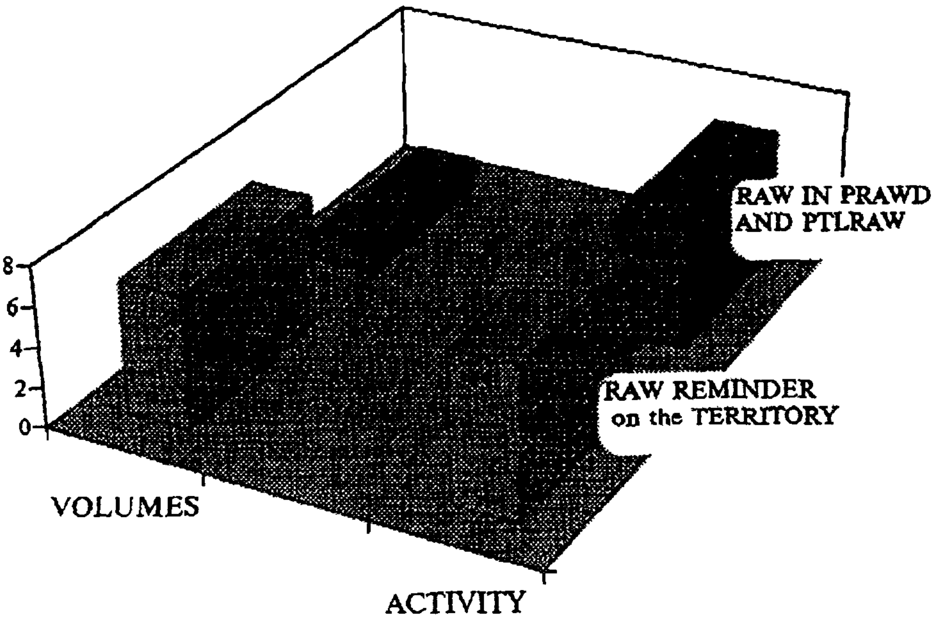
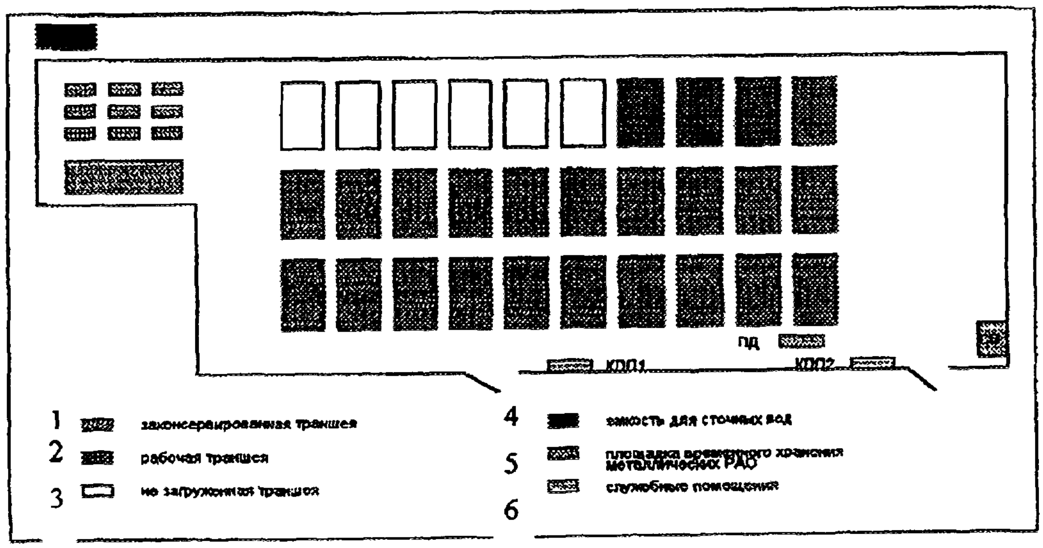
The peculiarity of Chernobyl exclusion zone is the existence of constant and a lot of temporary points of radioactive waste of Chernobyl origin disposals in it.
Chernobyl zone (exclusion zone) is the territory round Chernobyl NPP restricted in the result of Chernobyl accident with no inhabitants in it and where the economic activity was almost stopped.
The exclusion zone is characterized by the irregular (spotted) distribution of radionuclides and large range of physico-chemical and radioactive composition variations, that is connected with specific radioactive releases and meteorological circumstances in the period of throwing of radionuclides from the destroyed reactor to the environment. The distinction of the zone radioactive contamination is the existence of large quantity of "hot particles", and also fuel fallings in the zone adjacent to the ChNPP [1].
Reference assessments of the RAW volumes that are situated in the exclusion zone are shown at Pic.1 [2]. In the process of territory decontamination during 1986 - 1995 substantial part of RAW which was concentrated at the most contaminated separate plots was localized and placed to different disposals[3]. At the same time in the zone there still is large enough quantity of RAW distributed round the zone the localization of which requires more developed technologies and equipment.
In Chernobyl exclusion zone there are two types of disposals. They are as follows: points of radioactive waste disposal (PRAWD) and points of temporary localization of radioactive waste (PTLRAW), that were founded in 1986-1987 during the liquidation of the consequences of the Chernobyl accident.
Nowadays the main point of low and middle activity radioactive waste disposal (with the levels of γ-contamination up to 1 R/h) in the zone, to which the RAW generated from the decontamination of territory and equipment are put up is PRAWD "Buryakovka".
PRAWD "Buryakovka" started its operation in 1987 and is situated in 12 km from ChNPP. PRAWD is consists of 30 disposal trenches with clay screen on the foundation and slopes. In addition on the bottom and entrances the iron and concrete slabs are laid. The scheme of PRAWD "Buryakovka" is shown at Pic.2. The project capacity of the PRAWD "Buryakovka" is 450 thousand m^3. At present time there are 22 filled up trenches in PRAWD in which about 65 thousand Cu of activity is placed.
At Pic.3 the volumes of RAW disposal in PRAWD "Buryakovka" are shown.
The shortcoming of the RAW disposal in PRAWD "Buryakovka" is that the buryings were loaded mainly in bulk, and then were rammed by the hard machinery (bulldozers, tractors, etc.). The special compaction equipment was not used, because of that the trenches were filled up very quickly. In the nearest future the disposals of PRAWD "Buryakovka" will be filled up completely.
The radiation dosimetric control is carried out by the dosimetrist by hand with the help of portable devises.
Nowadays the apparatus is developed, the test and assembling of the automatic radiometric control system are conducted. All the results of the radioactive waste mass measurement brought to the PRAWD by car automatically put into the PC. The devises of radiation control are moving above the RAW surface with the help of robot-manipulator. The data is registered and processed by the PC with next transmission to the controller's office for documentation. The special enterprise that provides the RAW management and decontamination in the exclusion zone is "Komplex" a region center for calculating the movement of RAW within the Chernobyl zone.
The delivery of RAW to the PRAWD is produced by special cars in circulating or single containers or loaded in bulk in the body of lorries with the closed roofs.



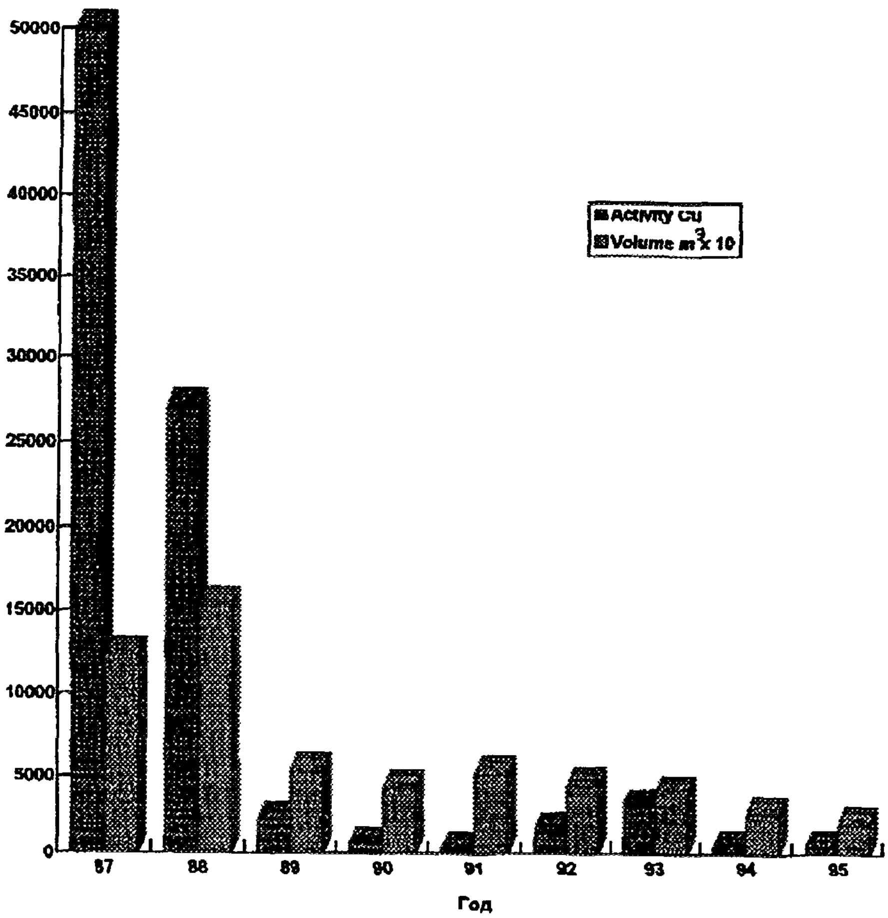
Pic.1. Distribution of Radioactive Waste in Exclusion Zone (Data of STCCMRAW and STC RIA "Pripyat"



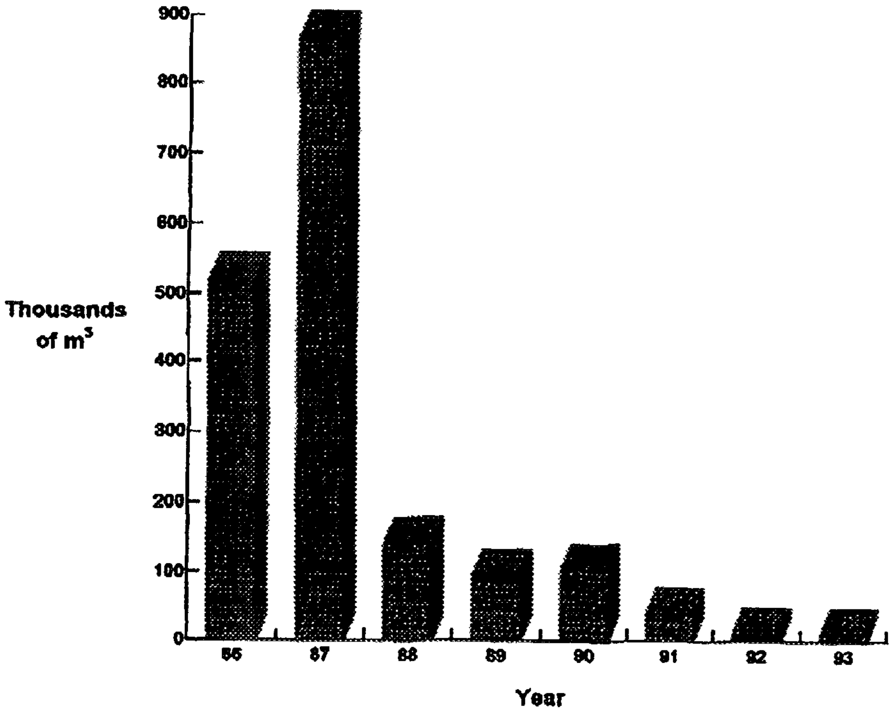
Total Square: 1км^2
Project Volume: 450 000 m^3
Term of Exploitatnon: 30 years

Picture.2. Scheme of PRAWD "Buryakovka"

1. **Filled up with RAW and laid up trench**
2. **Filling up trench**
3. **Prepared for Filling trench**
4. **Tank for sewage**
5. **Ground for temporary disposal of metal RAW**
6. **OFFICIAL PREMISES**



Picture 3. Volumes and total activity of RAW in PRAWD "Buryakovka"



Picture 4. Total Volumes of RAW in investigated PTLRAW

Along the roads and at the places of unloading the RAW dust-neutralization is providing regularly. At the adjacent places to the roads, at other dust places the dust-fastening is providing periodically.
Unloaded specific autotransport and circulating containers are decontaminated before leaving the PRAWD and are checked out.
Preservation of filled up trenches is carried out by the clay screen 0,5 m of thickness packed with the special technology. Clay screen is covered with the protective local ground layer 1 m of thickness, after that they plant perennial grass.
The disposal of RAW is prescribed to last not less than 30 years.
There are more than 800 PTLRAW in the exclusion zone. Most of them were created in the places of accumulation of RAW during the liquidation of the consequences of Chernobyl accident in 1986-1987 aiming the decreasing of the radioactive contamination levels at the working places Pic.4.
PTLRAW is a simple-in-construction engineering building containing RAW implemented as the trench or on surface rampart without any hydroisolation and with the soil on its surface. The project, executive documents and topographic tie are absent.
Construction of the RAW disposal tanks in PTLRAW is not appropriate to the Sanitary rules on the RAW management STRAWM-85.
At present investigation is being carried out of the PTlRAW plots "Red forest", "Stroibaza", "Yanov station", "Peschanoe plato (Sand plateau)", "Kopachi", "Neftebaza", "Pripyat".
Especially large RAW supply is situated now in PTLRAW "Red forest", the same time the most inauspicial PTLRAW from the point of view of the possibility for radionuclides to occur in the Pripyat river are PTLRAW "Neftebaza", "Pripyat", "Peschanoe plato" which are close to the river. During the flood-time in 1991 the concentration of Sr^{90} increased in 10 times because of close to river PTLRAW. This circumstance determines the priority of the works on the localization of PTLRAW or necessity to take measures aiming decreasing of the radionuclide distribution danger from the exclusion zone.
Nowadays the project of PTLRAW "Neftebaza" conservation is developing and they provide the investigation of other plots.
While working on revealing and specifying the situation of PTLRAW the outlines of RAW concentrations are defined by special radio wave device. The measurements of radioactivity of the district and preparation for the following investigation are provided.
Then the soil samples are taken from enough depth for the spectrum analysis. γ-exploration of the ground is providing on the 1 m depth at the 10 x 10 m net. STC CMRAW together with State enterprise "Komplex" fulfil all the work on PTLRAW investigation.
When PTLRAW is revealed the radionuclide content of RAW, total radionuclide activity and geometrical characteristics of it are defined. The lithological cuts and sections of RAW disposal plots are constructed. The cartograms of surface radiation contamination are completed and radionuclide activity supply in 5 cm surface layer is calculated, disposal heating and the cases of partial blooding of RAW are evaluated. All the radionuclide contamination has been investigated, prognosis of radionuclide migration and of ground water contamination was completed.
After the results of investigation the cards of inventory were worked out, data was input into the PC and on the figure maps of the exclusion zone.
Data received is the basis material for ecological assessment of RAW disposal effects on the environmental objects and for developing the measures of making them safe.
The ground water radioactive contamination control is carried out with the help of control and observe slits which are situated on the directions of underground water floating out of the districts of PRAWD and PTLRAW. There are about 250 control and observe slits for taking samples in the zone.
The results of analysis of operation of PRAWD are used for correcting the work on the creating of the enterprises for RAW processing and long term (up to 300 years) controlled RAW disposal (project "Vector"). On the basis of enterprise complex "Vector" it is proposed to create the Center for processing and disposal of the low and middle radioactive waste of different types [4].

LITERATURE

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LIST OF ACCEPTED ABBREVIATIONS

RAW	- Radioactive Waste
PRAWD	- Point of Radioactive Waste Disposal
PTLRAW	- Point of Temporary Localization of Radioactive Waste
STC CMRAW	- Scientific and Technical Center on Complex Management of Radioactive Waste
NPP	- Nuclear Power Plant
PC	- Personal Computor
ChNPP	- Chernobyl Nuclear Power Plant
RIA PRIPYAT	- Research and Industrial Association Pripyat
CAP	- Control Admission Point
RCP	- Radiation Checking Point
OP	- Official Premises

EFFECTS OF THE CHERNOBYL ACCIDENT ON RADIOACTIVE CONTAMINATION OF GROUNDWATER UTILIZED FOR WATER SUPPLY

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1. INTRODUCTION

According to the notions of classic hydrogeology, the groundwaters of deep-laying aguifers were considered to be safely protected against various external contaminants, due to high sorption properties of aeration zone soils, regional distribution of aquitards, and very long period of ground water formation.

However, after a number of large-scale technogenic accidents with the Chernobyl accident at the top of this list, and subsequent mass determinations of contaminating substances in ground water, the anomalously rapid penetration of newest pollutants into groundwaters was revealed even for deep-laying aquifers. So, in groundwater with the calculated age of about several hundred years, the pesticides were detected used in agriculture since 1970s-1980s, as well as radionuclides of undoubtedly Chernobyl origin.

Contamination of upper subsurface aquifer and a part of artesian aquifers is exclusively significant in Chernobyl exclusion zone characterized by high levels of surface contamination with radionuclides.

However, significant groundwater contamination with radionuclides was also registered at the periphery of area subjected to the Chernobyl radioactive fallouts, including some wells used for potable water-supply. This fact provides the necessity for more intensive studies and forecasting of radioactive contaminants migration processes in groundwater.

2. REVEALING POSSIBLE MIGRATION PATHWAYS

In the course of analysis of the mechanisms of radioactive pollutants transport into groundwater, along with the usual infiltration way, the two "untraditional" ways of migration were revealed which in a significant measure pass aside the natural sorption buffer of the geosphere.

The first way of anomalously rapid contaminants migration into groundwater is "technogenous", caused by imperfect construction technology of water intake wells or by low quality of their casing. During operation of high-rate submersible electric pumps, the cone of depression occurs in the near-well space of artesian aquifer water intake with a water head drop approaching tens of meters. Due to this fact, the water moves along the cavities, caverns and fissures in the well annulus space downwards from upper aquifers.

The possibility of such a way for contaminants to enter deep artesian aquifers was confirmed by experimental works at the Kiev water intake wells. In these experiments the injections of NaCl into the upper subsurface aquifer were applied at a distance of several dozens of meters from a high pumping rate well, exploiting the aquifer at 250m depth. Increase of the chlorine ion content in pumped-out water was observed just a few days after the injection. This fact indicates the possibility of fast penetration of contaminant into deep-laying aquifer along the annulus well space, bypassing the natural sorption barriers

The second way of anomalously rapid migration is associated with zones of crustal weakness. In contrast to the zones of weakness in crystalline rocks and karsting limestones which are obvious and represented by fractures and rock cavities, the revealing of heterogeneity in permeability of nonfacial unconsolidated sediments is a pioneering work done by hydrogeologists of the R&D Center of Radioecological Studies of the National Academy of Sciences of Ukraine.

The tectonically active zones and depression morphostructures were chosen as primary objects for studying possible moisture and contaminants fast migration through aeration zone into groundwater. Their studying included large-scale decoding of aerial photographs and topographic maps, emanation profiling of hypothetical active zones and surrounding background areas, detailed analysis of physico-mechanical, water-physical, chemical, electric and other soils properties, accomplishment of regime observations over the moisture migration in the aeration zone, water levels and chemical content of groundwater.

The conducted investigations allow to make the conclusion that granular collectors in unconsolidated sediments are characterized by essential inhomogeneity of filtration and migration properties. Zones of anomalously rapid migration are marked by linear and circular depressions in the landscape and characterized by high emanation ability of unconsolidated sediments, their increased moisture and electric conductivity. The soil profile cut in these zones differs from that of the background areas, the ground water levels dynamically response to the atmospheric rainfalls, that is clear from anomalously high infiltration rate and the formation of spreading cupolas on groundwater level surface after the period of intensive rainfalls (see Fig. 1). Analysis of radionuclides content in the solid phase of soil profiles indicates more intensive vertical migration in the active zones (see Fig. 2, 3).

3 MODELING RADIONUCLIDE MIGRATION IN GROUNDWATERS

In parallel with the experimental studies of radionuclides distribution in groundwater we perform mathematical modeling of the migration processes, based on geological section data, filtration and sorption parameters of water-bearing beds, initial values of surface contamination by radionuclides and the present values for their concentrations in different aquifers. Modeling is carried out by our original programs, allowing to develop the conformed prognosis and epignosis of radionuclide migration in geological medium.

Starting from 1991, we accomplish the investigations on the assessment and forecasting of groundwater contamination with radionuclides of Chernobyl origin over the territory of Kiev industrial agglomeration. In the vertical section, the 4 water-bearing aquifers are being studied, including the Quaternary aquifer (depths to 20 m), the Eocene (depths to 130 m), the Cenomanian-Callovian (depths to 200 m), the Bajocian (depths to 250-300 m). In all these aquifers the contamination of groundwater with ^{137}Cs in the range of n 10^{12} Ci/l (0.037n Bq/l) was observed, where n ranges from 1 to 9.

To obtain the modeling assessment of geological rock medium contamination in the Chernobyl exclusion zone and Kiev region we performed the modeling of ^{137}Cs vertical convection-dispersion transport for the typical profiles of these regions with downgoing infiltration flow rate of about 100 mm/year, taking into account the interaction between the solid (absorbed) and liquid (dissolved) fractions of contaminant. For both regions the models were calibrated in accordance with observed data for the contaminant content in liquid and solid phases at different depths. According to these data, in the Chernobyl exclusion zone the ^{137}Cs concentrations in solid phase within the upper 15 m layer are of the order (1-10) $10^{[illegible]}$ Ci/dm^3 and in the liquid phase of 10^{10} - 5 10^{9} Ci/l, but at the lower part of the profile, at the depths of 60-100 m the concentration in water remains within the limits of (1-10) 10^{12} Ci/l. Starting from these values, the distribution coefficients K_d were assessed and forecasting concentrations till the year 2050 performed

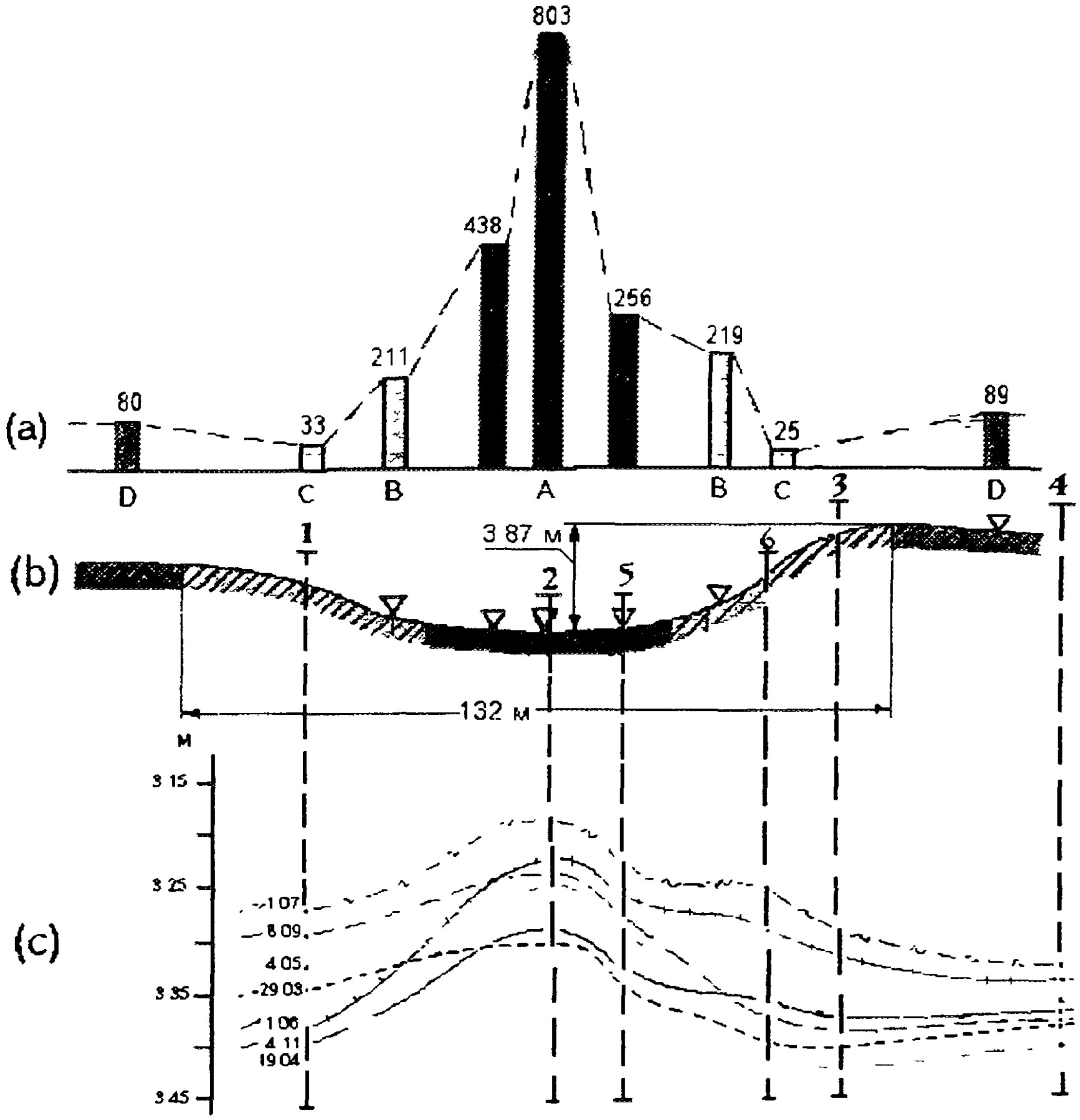

Fig. 1. The sheme of infiltration flow rate and variations of groundwater levels for the upper subsurface aquifer:

(a) - infiltration flow rate of upper subsurface waters according to hydrophysical data (in millimeters);
(b) - the surface profile of the depression zone;
▽ - hydrophysical observation sites;

2 - wells and their numbers;
(c) - groundwater level variation in time;

1 07 - date of measurement: (day, month in 1995);
(d) - zones: A: central, active; B: transitional, C: slope; D: background

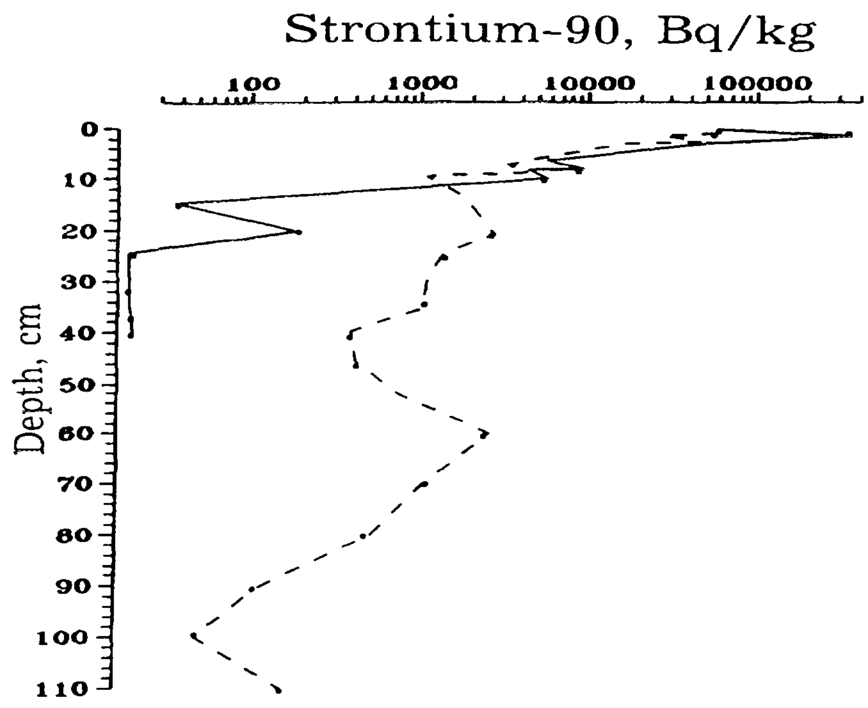

Fig. 2. Sr-90 content in soilprofile of the Veresok tract:
solid line - the border of the depression
dashed line - the bottom of the depression

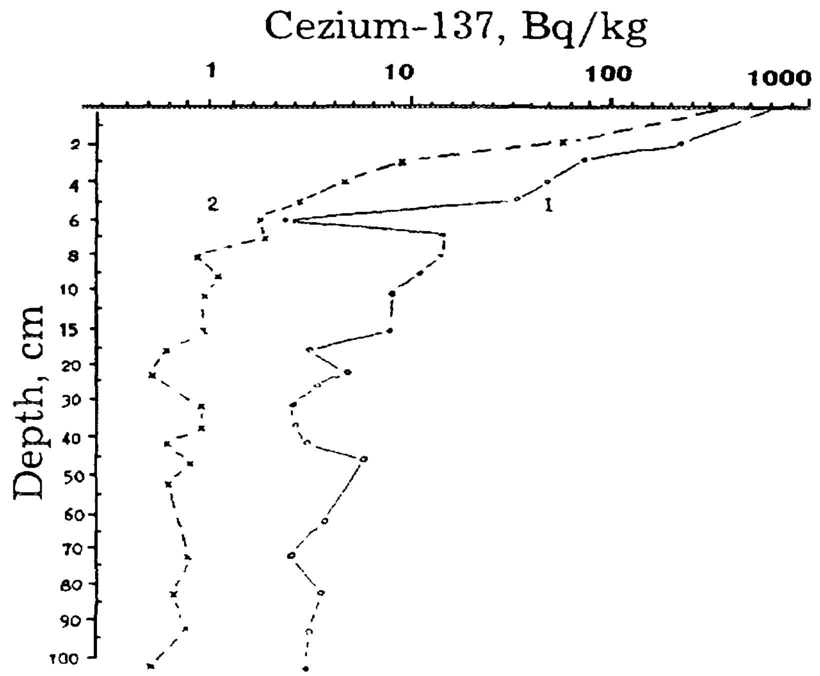

Fig. 3. Cs-137 concentration (Bq/kg) plots against depth for the sediments at the reference site of Liutezh testing area
(1) - depression profile
(2) - background profile

The results for the concentrations in groundwaters of Kiev region as plotted against depth for the years 2000, 2010, 2020, 2030, 2050 are shown on Fig.4. On Fig. 5 the forecasted ^{137}Cs total contents in solid phase of upper 1m-thick and remaining 1-100 m layers are shown as recalculated to corresponding surface densities (Ci/sq.km) plotted against time for the Kiev region.

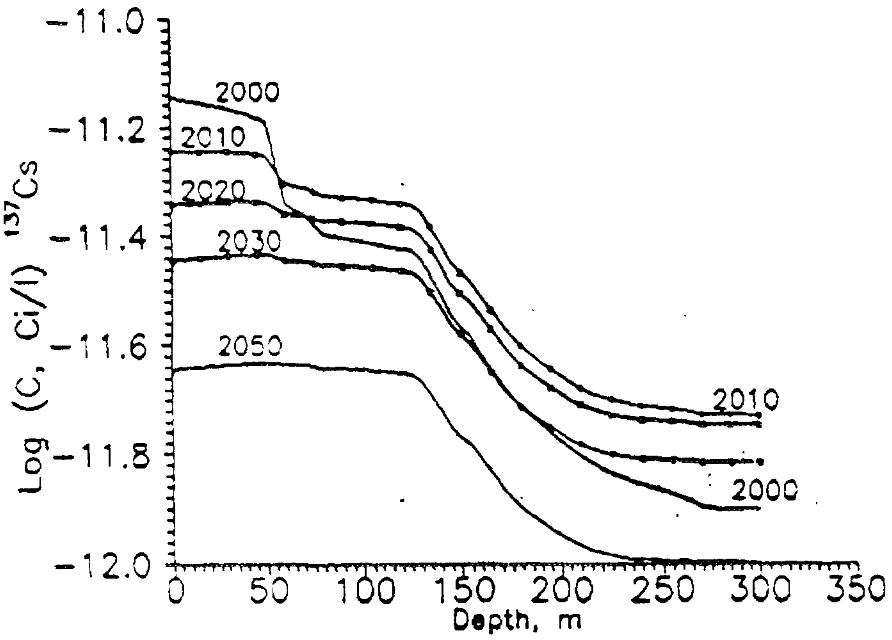

Fig. 4 Predicted concentrations of ^{137}Cs in groundwater (Kiev region) till the year 2050

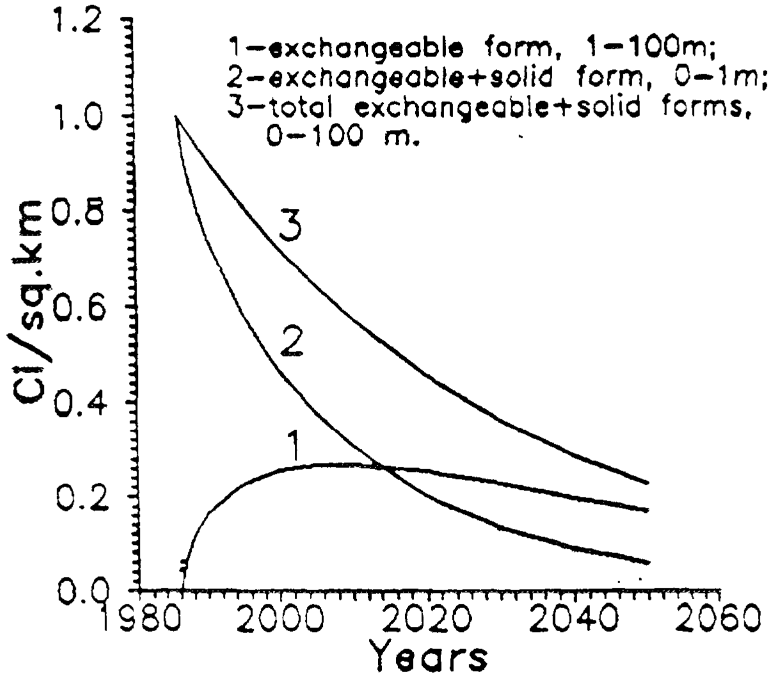

Fig. 5. Forecasted ^{137}Cs content in geological rock medium till the year 2050 for upper 1 m and 100 m-thick layers (Kiev region), recalculated to surface densities

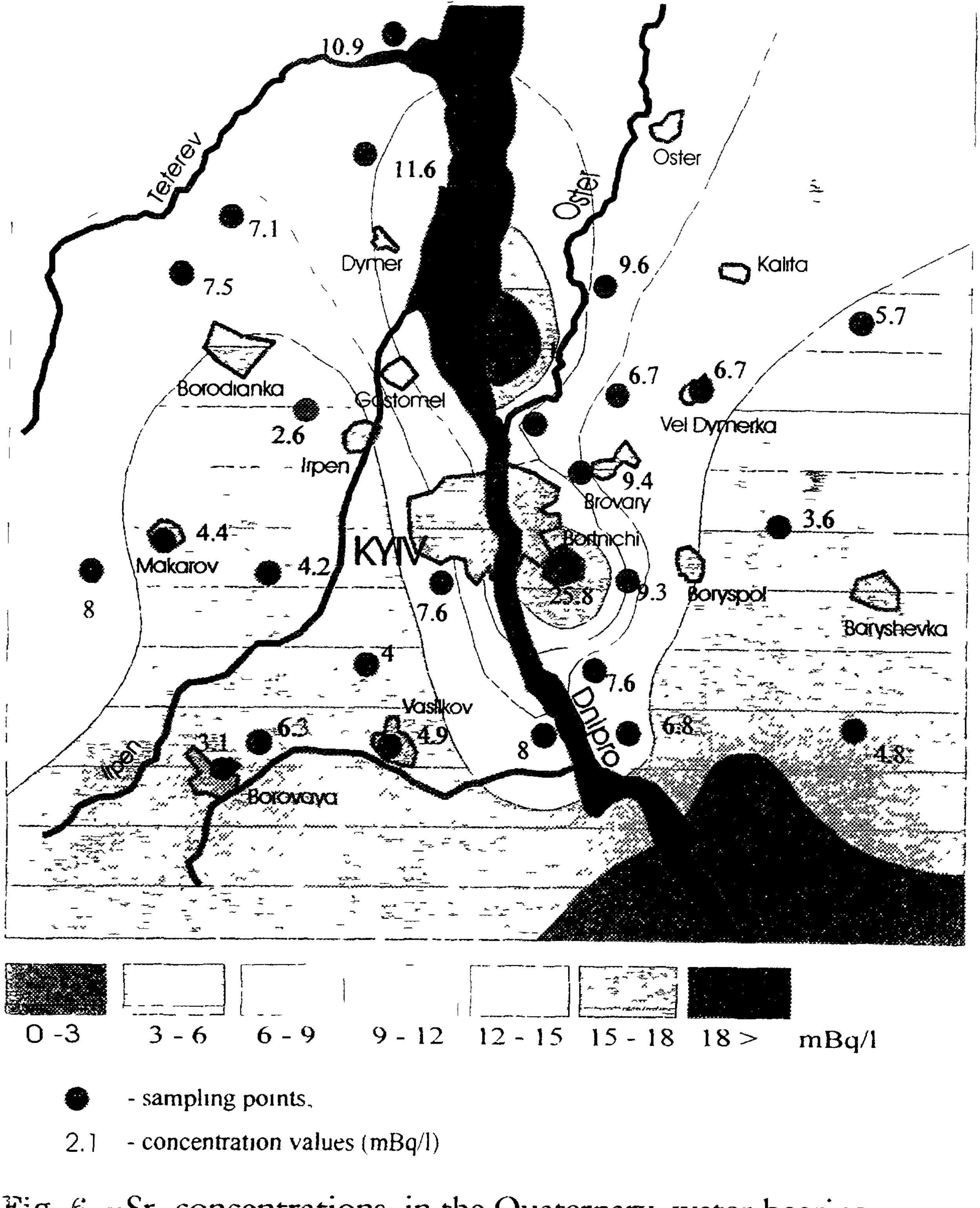

Fig. 6. ^{90}Sr concentrations in the Quaternary water-bearing complex within the territory of Kiev industrial agglomeration.

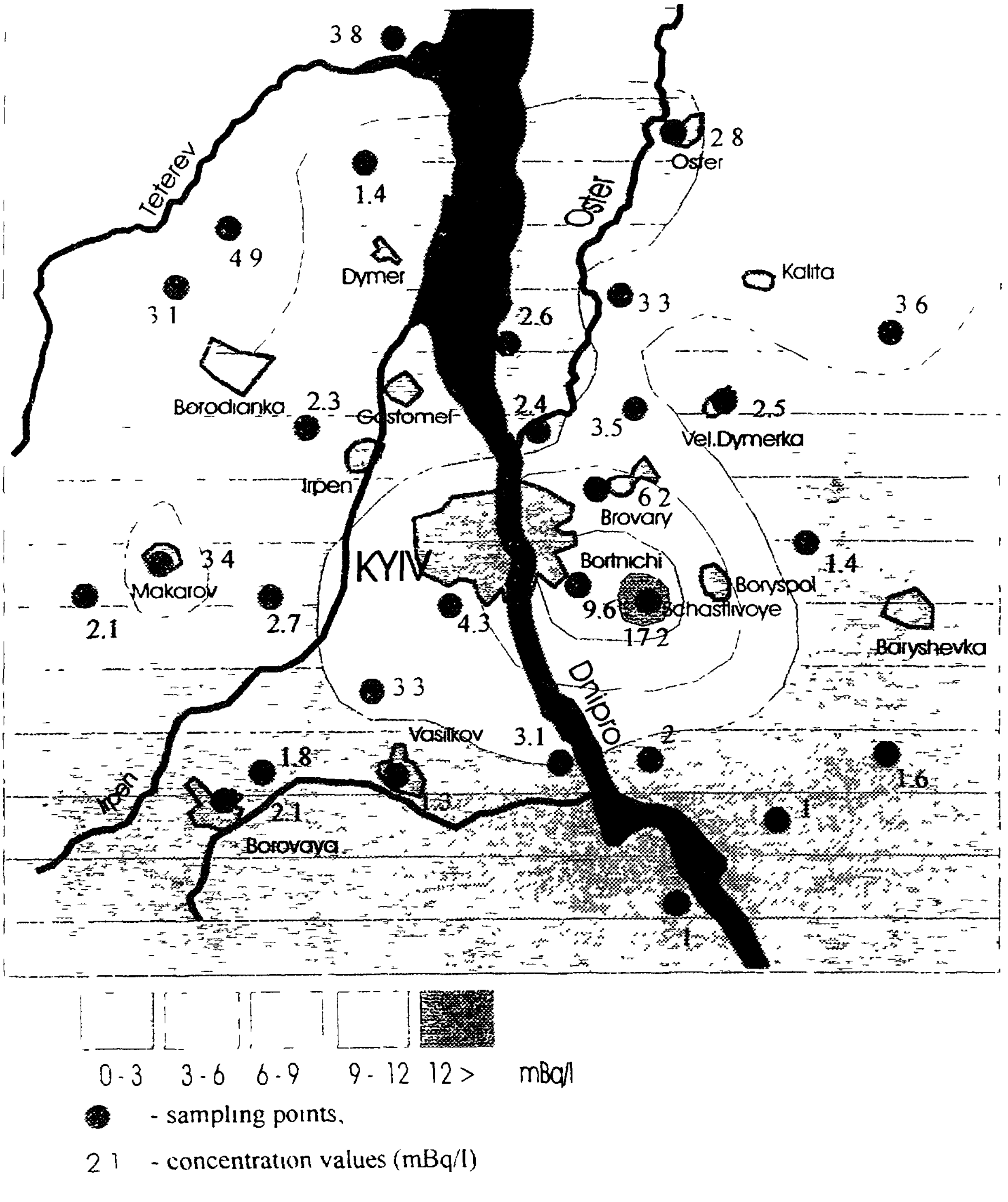

Fig. 7. ^{90}Sr concentrations in the Eocene water-bearing complex within the territory of Kiev industrial agglomeration.

4. CONCLUSIONS

1. The analysis of modeling solutions obtained enables to accept the possibility of accumulation in the geological rock medium up to 30% of the sum of initial surface fallout contamination. This states in favor of the concept of anomalously fast migration pathways, but from the other hand, indicates the important role of geological rock media as a powerful protection buffer, as related to the biosphere, on the way of contaminants penetration from the surface into groundwater.

2. The maximum contamination concentrations in groundwater and geological rock medium with ^{137}Cs will be observed in the Kiev region in 2000-2010s at the depths of 20-50 m ranging to $8\cdot10^{12}$ Ci/l in water to $2\cdot10^{11}$ Ci/dm^3 in solid phase. At the depths of 60-100 m the maximum concentrations are expected in 2010-2020s to $2\text{-}3\cdot10^{12}$ in water and and to 10^{11} in solid phase. For the Chernobyl exclusion zone, the corresponding maximum values expected in 2010-2020s in the upper 20 m layer are sufficiently higher (by 2 orders of magnitude), but at the depth of 80-100 m the concentration in liquid phase remains within the range of $(1\text{-}5)\cdot10^{12}$ Ci/l.

3. The results obtained by direct measurements and modeling for ^{90}Sr provide the evidence that observed and forecasted contamination with this nuclide (see Fig. 6, 7) is sufficiently lower than maximum permissible concentrations. Nevertheless, these data require to be periodically precised based on monitoring which is necessary to organize.

4. Concerning contamination of groundwater with radionuclides, the Pripyat water intake is one of the most unfavorably located among those operating in the Chernobyl exclusion zone.

Performed analysis indicates that there is poor evidence in nearest 70 years for contamination of Pripyat water intake by ^{90}Sr (with exceeding the limits of highest permissible concentration), one of the most rapidly migrating element. The economic risk appraisal of water intake wells contamination according to the theory of cost-benefit analysis indicates that conducting the large-scale water protection measures at Pripyat water intake presently is not actual.

The efforts should be concentrated at methodologically grounded groundwater monitoring of artesian aquifer and also of upper subsurface aquifer in the close (500-1000 m) locality of water intake wells.

In 5-10 years the prognosis should be precised based on obtaining additional specific monitoring data of ground water contamination and sorption properties of soils and water-bearing beds, that would reduce the uncertainty in modeling parameters. Then, the decisions on water protection measures should be revised.

LONG-TERM TREND OF RADIOACTIVE CONTAMINATION OF FOOD PRODUCTS IN BULGARIA AFTER THE CHERNOBYL ACCIDENT

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МНОГОГОДИШНЫЙ ТРЕНД РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ ПИЩЕВЫХ ПРОДУКТАХ В БОЛГАРИИ ПОСЛЕ ЧЕРНОБИЛСКОЙ АВАРИИ

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(расширенный реферат)

С цели мотивации некоторыйх констатации и выводы представляется извлечение данн (общий брой 55272) для периода 1986-1995 г , демонстрирующее на фоне минимальных и средных стоимостей степень загрязнения с цезиевыми радионуклидоми основным пищевым продуктом самым высоким /максимальным и "пиковым"/ после "феномена" Чернобиля в Болгарии Презумция этого обстоятельства является то что где-то и когда-то было возможно консумирование таких продуктов не подвергнатые радиационного контроля

Среднеарифметические стоимости содержания Cs-134 и Cs-137 молоке коровь Южней Болгарии с 400 Bq/l в майе 1986 г (среднемаксимальный 720 Bq/l) упали на 50 Bq/l в сентебре. После того в рамках "второго радиационного пика" эти стойности повысились вновь до 400 Bq/l (690 Bq/l) при самои высокой стоимости выражающийся на 1231 Bq/l. Такого является картина и при мясом. Самыми высокими резултатоми получены при бараниной - средеарифметические стоимости повисились с мая 1986 г (150-201 Bq/kg) до июня (241-824 Bq/kg) и потом уменшились до ноембре (53-152 Bq/kg). С начале 1987 г начинается повишие до априле (400Bq/Kg) после которого следует понижение до ноембре (11-43 Bq/kg). При начальным загрязнением среднемаксимальные стоимости для Южней Болгарией не превысили 900 Bq/kg , а при вторичным - достигли 2600 Bq/kg при "пиковой" стоимости 7200 Bq/kg. Пшеничное зерно, урожай 1986 г было загрязнено как следует в Северной Болгарии (96+44 Bq/kg), в Южной Болгарии (330+101 Bq/kg) при максимальным содержанием 510 Bq/kg. Остальные пищевые продукты были относительно меньше загрязнены : молочные продукты - максимально 799 Bq/kg, пищи для детей - до 112 Bq/kg, остальные - до 69 Bq/kg, а лекарственные растение показали активность, достигающая до 40200 Bq/kg.

Сопоставляя представленых данных со стоимостях предельно допустимых норм, принятых тогда как в Болгарии (14.05.1986 г - 370 - 740 Bq/l,kg; 29.04.1987 г - 75 - 600 Bq/l,kg) так и международными организациями (370-600 Bq/l,kg), видно, что с одной, стороный в определенных периодах времени для некоторых пищ и в некоторых районах было необходимо принят радиозащитных мерок с цели уменьшения дополнителного лучевого нагружения населении, а с другой - определенная часть некоторых пищ необходимо было отклонять с реализации стокового фонда населения и с экспорта. Например во время "второго радиационного пика" весны 1987 г 15-50 % молоком коровь Южней Болгарии не следовало консумироват, а за периоде майя 1987-июня 1987 г 22 % из партид мяса попали под радиоционно-гигиенного запрящения.

Сравнивая степень загрязнения с цезиевых радионуклидов с обще фолаутного из ядерных взрывов до 1963 г, например при пшенице и ее продукты помола получилось, что она на 75 раз больше. Содержания этих двух радионуклидов в молоке , мясе и пшенице в стороны из затронутого региона /Австрия, Греция, Венгрия и Германия', было как следует с 23 - 70 ; с 1.3 - 46 и с 22 - 8.0 раза меньше тем в Болгарии Это можно использовать как обьяснение факта, что несмотря на того, что по сумарного отклалывания J-131 и Cs-134 + Cs-137 Болгария находится на восьмом месте среди европейских стран, она занимает первое место по инкорпорацией в организме J-131 у детей и цезиевых радионуклидов у взрослого населения К этим надо добавить и то, что несмотря на мальенких и болших пропусках и недосматриваниях, не было соблюдено и приложение принципа "АЛАРА".

После майя 1987 г началось относительно быстрое уменьшение содержания цезиевых радионуклидов в молоке на 10 Bq/l и в мясе до 45 Bq/kg (к ноембре того же года) Осредненые стоимости для целой стороне о наличие Cs-134+Cs-137 в пшеничном зерне, урожай 1987 г (8.8 + 3.0 Bq/kg) показали на 26 раз уменьшение по сравнению с 1986 г (230 +- 142 Bq/kg)

При определенных пищевых источниках Чернобилское загрязнение однако оказалось прочно "Пиковые" стоимости ювляются эти на многолетных лекарственных растении, сухим грибом и бараниной Минимальные стоимости (2 - 13 Bq/l,kg) которые встречаются часче показывают отзвучание события. Максимальные (5 - 278 Bq/l,kg) - то что большая част пищи болгаров перетерпели соответное "Самоочищение" "Пиковые" (117 - 7142 Bq/l,kg) - показывают необходимость из перманентного радиационного контроля

Приведеная информация относится к радиационному статусу и его динамику за периоду 1986 1995 г Она дает возможность сделать констатацию, что сегодня как основные 15 пищевых продуктов и осталыные продукты из "продовольственой корзиной" лимитирующие пищевую диету болгаров, можно консумировать Взнос цезиевых радионуклидов с нормальную пищевую диету в организме болгаров понастоящему можно сопоставить с тот-же самой с 1985 г, должимый глобальных радиоактивных отложении после прекращения экспериментальных ядерных взривов.

XA9745862

STRUCTURAL-GENETIC APPROACH TO ANALYSIS AND MAPPING OF CHERNOBYL'S RADIONUCLIDE CONTAMINATION FIELD

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The near ChNPP zone (20 to 60 km from the nuclear power plant) is an area of most intensive radioactive contamination, the density of which (being in the center) 1,000 to 10,000 Ci/sq.km (for ^{137}Cs and ^{90}Sr), 20 to 200 Ci/sq.km (for the sum of alpha-radiating isotopes of Pu, i.e. ^{238}Pu, ^{239}Pu, ^{240} Pu and ^{241}Am.[1] The field of radionuclide contamination in

[1] In Ukraine the density of radionuclide contamination, at high levels, is measured not in kBq/sq.m but in Ci/sq.km, 1 Ci/sq.km is equal to 37kBq/sq.m.

this zone is most complicated and contrast. This causes, to large extent, considerable distinctions on different maps made during last decade. In its turn, this ambiguity of mapping results hinders to reveal main structural (two - dimensional) patterns of this field. Meantime, the significance of such structural patterns is very high in study of genesis (i.e. of nature of definite mechanisms of formation of the radionuclide contamination field during 26.04.86 to 10.05.86) as well as purely practically in predicting the specific levels of contamination in one or another place, i.e. in refining maps of contamination, in particular in the intervals between the existing test points.

As a main tool for revealing and interpreting the internal structure of radionuclide contamination field, around the Chernobyl NPP the reliable and validated detailed scale maps of contamination densities could serve. Such maps should have, on the one hand, a high enough density of initial observation points (not less than 1 to 10 points per 1 sq.cm. of final map) and, on the other hand, a high representativeness of each observation point, i.e. reliability of presentation of its vicinity (0.1 to 1 sq.km). The available analytical data files of soil sampling in the exclusion zone conform neither to the first requirement, nor to the second one: real density of sampling does not exceed 0.2 to 0.5 points per 1 sq.m, and the representativeness of obtained results has a typical variation from medium values (in the neibourhood of 0.1 to 1 sq.km) to 3 to 5 times.

Results of airgammaspektrometry mapping on the scales of 1:100.000 and 1:25.000 formally meet both main requirements but today they give estimations only on density of ^{137}Cs (estimation on ^{241}Am is possible on densities being more than 0.5 Ci/sq.km). Besides, these estimations are not direct (contact) ones but indirect (distant) that sharply diminishes the possibility of their reliable metrological support. In particular, the variations of landscape/geomorphology characteristics of the locality which are difficult to take into account (of special note are levels of humidity in soil and in lower layer of atmosphere) lead to variations in readings of an instrument to 2 to 3 times at the constant level of soil contamination with ^{137}Cs, and the sum of all sources of errors brings up this factor to 3 to 5 times. In spite of a very significant file of analytical data on the Chernobyl exclusion zone and its surroundings, as well as of many of tens of drawn maps presenting the radiation situation and levels of radioactive contamination of the locality, until recently there were neither unified summary map (conditional enough on the scales 1:200,000 and more detailed) of contamination fields of the Chernobyl exclusion zone, nor clear notion of internal structure of these fields.

The team of specialists from seven different institutions/organizations of Ukraine tried to resolve this twofold problem, i.e. to decode the structure of radionuclide contamination field in the near zone of ChNPP and to draw a faithful map for ^{137}Cs on the base of generalization/synthesis of accessible to date materials obtained over the course of 10 years. It has been possible to collect and generalize more than 75 to 80 per cent of data available in Ukraine. Real prerequisites exist for applying the rest of trustworthy materials this year. In the whole, about 40 sources of primary information maps and tables have been already analyzed and taken into account.

Generalization and synthesis of sets of dissimilar data (not rare are ones being considerably different from others) were carried out with the use of following main principles (including those of stochastic mapping):

- taking account of real representativeness (trustworthiness) of starting data, i.e. creation of most simple graphical model of contamination field, statistically not contradicting the factual evidence;
- priority given to most trustworthy data (in particular, to the surface ones over the AGS ones);
- priority of high estimations of contamination levels over the low ones;
- structural conditionality and interpretability of maximum number of elements taken from a drawn field of contamination.

The last means striving for correspondence of final map and of its separate fragments with available model presentations concerning the mechanisms/course of formation of radionuclide contamination of the locality with emissions from destroyed reactor of 4th unit of the ChNPP.

In our opinion the positive structures of contamination field on the territory under investigation could form in two main ways:

- dry deposition from separate jets of radionuclide material in atmosphere that led to formation of linear radial/jet structures having predominantly fuel form of fall-outs (dioxides of uranium, their alloys with zirconium etc.);
- rain deposition of (principally) condensation material from higher layers of atmosphere (abrupt enrichment with isotopes of ^{134}Cs, ^{137}Cs, partly of ^{106}Ru and insignificantly of ^{90}Sr) that resulted in formation of less regular and not linear structures and often isometrical or "palmated" structures (not infrequently having an orientation evidently different from the radial one) in the locality.

On the whole, the work was made on the cycle: initial model representations, their comparison with factual data on activities of ^{137}Cs in reference points, refinement of local graphical models and of their parameters, repeat comparison with factual evidence, synthesis of model forms and factual data in the form of final cartographic representation.

Main practical result of the work was to obtain a generalized map of retrospective estimation of locality contamination with ^{137}Cs at the distances from the ChNPP of 40 to 80 km. The map has been drawn in the scales 1 : 100.000 and 1 : 200.000. The general picture of contamination field is depicted appreciably more detailed than on the maps made before (12 gradations are highlighted instead of 5 to 8) and as a whole looks much more regularly. Densities of contamination on the entire map and in the territory of the Chernobyl exclusion zone of Ukraine vary from 0.2 - 0.5 Ci/sq.km to 1,000 - 10,000 Ci/sq.km and even more, i.e. the contrast range of contamination levels on this radionuclide in the Chernobyl exclusion zone reaches 4 to 5 orders.

In general, one could recognize four basic types of structural elements in the contamination field:

- central "volcano-like" structures having hyperbolic growth of activities toward the center (territory of the ChNPP);
- linear/radial zones of increased density of contamination ("jets"), radiating outward from the center in, almost all azimuths; these "jets" seem to be 10 to 15 in number; a part of them is traced to many tens or even hundreds of kilometers in the overall territory of Ukraine;
- local positive structures of a "superimposed" nature, separated from the central structure. This is a series of anomalies along the south-western trace ("Polesskoye - Narodichi jet"), activities in which being 300 to 900 Ci/sq.km, especially near the villages

Vesnyanoye - Dibrova, and a vast secant Radin - Kryukov structure to the north from the ChNPP (at the southern Byelorussian border) with the contamination density of 500 to 1500 Ci/sq.km. Judging from the radionuclide composition of contamination and from data of meteorology, all these local anomalies are composed predominantly of condensation material, and rain deposition.

In addition, such structural elements can be observed in the Chernobyl exclusion zone as relatively clean areas (contamination with ^{137}Cs less than 5 Ci/sq.km) which are enlarging in the direction to the boundaries of the Chernobyl exclusion zone. Three such zones of potential rehabilitation have been revealed. The principal one of them is Ilyintsy – Korogod zone (south-western sector of the exclusion zone) where the contamination level is lowered to 1 to 2 Ci/sq.km and even less than 0.5 or 1 Ci/sq.km. For purposes of comparison it will be remembered that in the neighbourhood of Kiev it is of about 0.7 to 0.9 Ci/sq.km.

Making the map allowed to find a number of areas reflected before with significant deviations from real levels of contamination, among which are the village Dibrova (discrepancy of 20 to 50 times) and south-western area of the exclusion zone (10 to 20 times).

The detail maps and block - diagrams were made to show the features of thin internal structure of separate areas having increased density of radionuclide contamination. These materials have been obtained on the test grounds "Krasnitsa" ("explosion" western trace of contamination, 12 to 14 km to the west from the ChNPP) and "Vesnyanoye" (south-western trace, 30 to 33 km from the ChNPP). The density of the observation net on the both test grounds was 100 x 100 m, i.e. 100 points per 1 sq.km. Block-diagrams of intensity of gamma-radiation from ground surface on the test ground "Krasnitsa" reflects a clear and regular linearity of typically "dry" fall-outs (in the near ChNPP zone) corresponding to the fuel component of Chernobyl ejection (concerning the composition). The "explosion" trace itself is split to 3 to 4 thin jets, to the large extent overlapping one another. The distance between the crests of these jets is only 200 to 300 m that causes very high anisotropy of radionuclide contamination field of this structure at the level of 1 : 20 to 1 : 50.

The map of density of soil contamination with ^{137}Cs on the test ground "Vesnyanoye" also represents evident anisotropy of this field, long axes of microstructures of which being oriented to the ChNPP. However there are two essential dissimilarities from previous case: anisotropy is expressed far weaker (at the level of 1:2 to 1:4), and among microstructures of the field the linear forms already are not prevailing but curved ones are. As a result, the total picture of the field becomes obviously turbulent. This is one more evidence (except anomalous relationship between isotopes of cesium, strontium and plutonium) in favor of hypothesis on rain genesis of this anomalous zone.

Those structural - genetic approach, having substantially higher precision of prognoses, was developed and justified to making the maps of a territory contaminated with products of radioactive ejection from the ChNPP in 1986. On the base of the developed approach and numerous initial materials, the inner structure of contamination field (in the territory of 40 to 80 km around the ChNPP) was decoded, and more reliable map of ^{137}Cs contamination density as of May 10, 1986 on the scale 1:200,000 has been made. More over made and published have been the maps of ^{137}Cs and sum of plutonium isotopes contamination of the territory of Ukraine on the scale 1:2,000,000. Making analogous maps for ^{90}Sr and ^{241}Am is now being completed.

It have to pay attention that present-day methods of computer mapping eiser embody the traditional "manual" techniques of making maps, or realize some universal models (kriging, spline-approximation etc.). Therefore, the application of modern computer technologies itself does not solve the problems of quality of the maps under consideration. The special models based on the structural - genetic approach allow to obtain the better consistency with the real environment state under complicated contamination conditions of the Chernobyl zone.

For computer embodiment of structural approach a set of original algorithms "STACHER" has been developed; development of the corresponding software may be accelerated with the availability of international cooperation.

ECOLOGICAL AND ECO-PHYSIOLOGICAL APPROACH TO ESTABLISHING RADIATION EXPOSURE STANDARDS

XA9745863

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The elements of radiation ecology and ecological physiology have been applied to work out methodology of assessment of radiation effects and their standardization after radiation disasters. A notion of regional rate of the natural radiation background in different parts of the Earth is introduced. Inclusion of the values of radiation background, technogenically intensified background, and medical radiation treatment through roentgenodiagnostic examinations to the value of basic and auxiliary limit of the yearly exposure is substantiated. Approaches to the creation of life maintenance systems in contaminated territories by minimizing dose exposures and rationally operating with their constituent parts, are suggested.

Специфическая эколого-радиационная ситуация после аварии на Чернобыльской АЭС (обширные зараженные территории, разнообразный спект осадков и т.д.) определила комплексный характер ее влияния на здоровье человека и разработку особых мер по поддержанию жизни [1]. Необходимо было разработать методологии и стандарты допустимого радиационного риска с точки зрения адаптивных возможностей организма, привыкшего жить в определенной естественной зоне. Это особенно касается Беларуси, которая получила наибольшее количество осадков. Массовая стрессовая ситуация привела к эндокринным, иммунологическим, нейрологическим и другим нарушениям [2].

Как известно, радиационная экология, являясь частью общей экологии, предметом своих исследований имеет радиоактивные вещества и радиоактивные излучения в связи с окружающей средой. В свою очередь, экологическая физиология занимается изучением адаптивных механизмов организма и его систем к различным факторам среды в пределах их нормальных и экстремальных значений.

Использование основ этих дисциплин в проблеме оценки радиационных воздействий и их нормирования и является предметом данного сообщения. С этих позиций и радиационный фактор, как и любой другой экологический фактор, может быть нормирован с учетом его особенностей и специфики воздействия на живые организмы.

Используются эколого-физиологические подходы для разработки нормативов дозовых нагрузок населения загрязненных послеаварийных территорий. Для этого предполагается ввести понятие региональной "нормы" дозовых нагрузок для населения различных регионов стран земного сообщества с учетом специфики естественного радиационного фона, техногенных и медицинских "добавок" при диагностических и лечебных мероприятиях с использованием рентгеновских лучей и лучевой терапии. Подчеркивается необходимость включения этих показателей (радиационного фона, техногенно-усиленного фона и медицинской радиационной надбавки за счет рентгено-диагностических обследований) в величину основного и вспомогательного предела годовой дозовой нагрузки.

Анализ данных "Каталога доз облучения жителей населенных пунктов Республики Беларусь" [3], включающий 3326 населенных пунктов, расположенных на территориях с плотностью загрязнения цезием-137 более 1 Ки/км^2, а также на территориях с плотностью загрязнения цезием-137 менее 1 Ки/км^2 , в которых по данным санитарной службы содержание радионуклидов в продуктах питания местного производства было выше установленного в республике норматива, показал специфику годовых суммарных эффективных доз облучения жителей населенных пунктов спустя 5 лет после аварии

Так, например, в г.Брагине Гомельской области, районе наиболее приближенном к месту Чернобыльской аварии и расположенному в зоне загрязнения территории Cs-137 15-40 Ки/км², в 1991 году годовая эффективная эквивалентная доза облучения составляла 2,5 мЗв (2 мЗв - за счет внешнего облучения и 0,5 мЗв - внутреннего облучения), в Ветке - 3,1 мЗв (1,9 - внешнее облучение, 1,2 мЗв - внутреннее), Буда-Кошелево - 1,3 (0,7 - внешнее и 0,6 - внутреннее), Корме - 2,0 мЗв (1,7 - внешнее и 0,3 - внутреннее) и т.п. Эти материалы свидетельствуют о том, что на территориях с плотностью загрязнения 15-40 Ки/км² к 1991 году еще остались места, где суммарные годовые эквивалентные дозы могут быть в пределах 2-3 мЗв в год. Таких мест из приведенных в каталоге более 3 тысяч населенных пунктов - несколько десятков и здесь проводятся дополнительные защитные мероприятия, состоящие в том, чтобы суммарные годовые дозовые нагрузки по внешнему и внутреннему облучению не превышали 1 мЗв.

Каждая из участвующих в создании дозовых нагрузок величин (естественный радиационный фон, техногенно-усиленный фон, медицинская надбавка, аварийная составляющая), носит переменный характер, каждая из них может быть оценена *современными средствами измерения и, что особенно важно, каждая из них может быть* учтена и изменена в нужную сторону при оценке общей суммарной радиационной нагрузки на организм и создания рациональных систем жизнеобеспечения.

Применительно к рассматриваемой проблематике под термином рациональная система жизнеобеспечения понимается минимизация дозовых нагрузок за счет разумного оперирования их составляющими [4].

В послеаварийном, как и в восстановительном периоде, важнейшим вопросом является определение величины дозовой нагрузки населения, которая бы обеспечила безопасность проживания и нормальную хозяйственную деятельность людей.

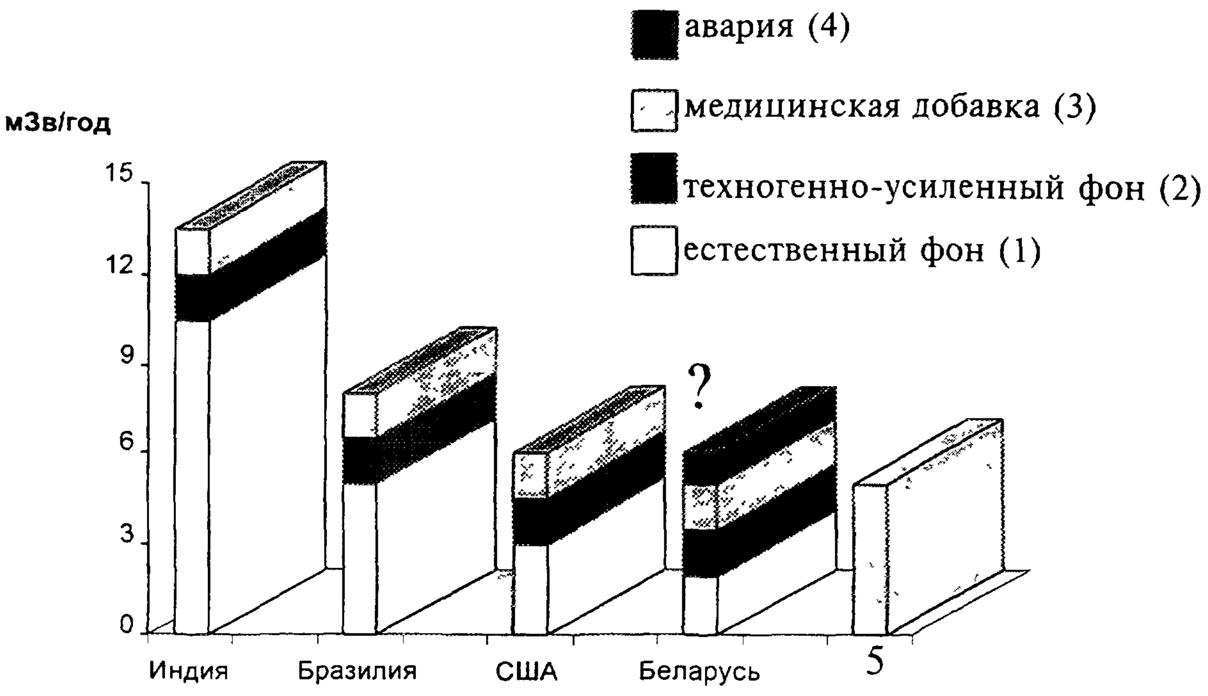
Следует напомнить, что в настоящее время точка зрения Международной *комиссии по радиологической защите (МКРЗ, Публикация 46, 1988) состоит в том, что* основным пределом является 1 мЗв в год. Однако можно использовать вспомогательный предел дозы, равный 5 мЗв в год для нескольких лет, при условии, что средняя годовая эффективная эквивалентная доза на протяжении всей жизни не превышает основного предела (1 мЗв в год). Пределы доз, рекомендованные комиссией, складываются из суммы эффективной эквивалентной дозы в результате внешнего облучения в течение 1 года и ожидаемой эффективной эквивалентной дозы, полученной в результате поступления радионуклидов внутрь организма за этот год.

Однако в подходах МКРЗ к дозовым нагрузкам на организм есть определенное противоречие. Оно состоитв том, что лимитируется и определяется только величина основного предела дозы 1 мЗв в год над уровнем естественного и техногенного радиационного фона, т.е. лимитируется только маленькая часть дозового айсберга.

Возьмем следующий гипотетический пример (рис.1): если авария типа Чернобыльской была бы в известных всем аномальных местах, где высокий естественный фон дает среднюю годовую дозу 300, 500 или 1270 мбэр/год, то суммарная годовая нагрузка при прочих равных условиях (и по современным рекомендациям МКРЗ) составила бы (фон + техногенный фон + медицинская надбавка) соответственно: в Швеции, США (300+150+150) - 600 мбэр/год, в Бразилии (500+150+150) - 800 мбэр/год, в Индии (1270+150+150) - 1570 мбэр/год. Простые подсчеты показывают, что лимитирующим фактором в этих ситуациях является величина естественного природного *фона, т.е. экологические параметры радиационного фактора в конкретных условиях* жизнедеятельности человека.

Используя предлагаемый МКРЗ постулат (1 мЗв над фоновым и другими загрязнениями), мы видим, что суммарная годовая радиационная нагрузка ни в Индии (15,7 мЗв), ни в Бразилии (8 мЗв), ни в Швеции и США (6 мЗв/год) не укладываются в регламенты требований МКРЗ.

Следовательно, применительно к анализу оценки поставарийных ситуаций крайне необходимо точно знать фоновые (доаварийные) величины радиационных нагрузок и величины экспозиционных доз в интересующих нас местах.



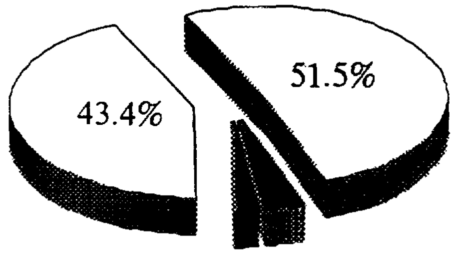


Рис 1 Составляющие параметры годовой средней эквивалентной дозы облучения от различных источников в некоторых регионах земного шара - мЗв/год (примерная схема).

1 - естественный радиационный фон, 2 - техногенно-усиленный фон, 3 - медицинская добавка, 4 - аварийная составляющая (рекомендованный МКРЗ основной предел дозы не должен превышать 1 мЗв/год), 5 - средняя доза на одно обследование методом компьютерной томографии - 5 мЗв. показана в том же масштабе для сравнения с рассматриваемыми параметрами. Знаком "?" обозначена доза различных дозовых нагрузок после чернобыльской аварии, требующих научно-обоснованного нормирования в восстановительном периоде

Анализ сказанного выше позволяет сделать несколько обобщений:

- при прочих равных условиях величина вклада природного радиационного фона в дозовые нагрузки на организм значительна, сильно колеблется и является во многих случаях "лимитирующим" фактором по отношению к возможным "добавкам" после радиационных катастроф;

- чем ниже был естественный радиационный фон до аварии и загрязнения, тем больший "лимит" на загрязнение может быть отпущен;

- за счет создания экологически-радиационно-чистого "дома" и регламентации жизнедеятельности можно уменьшить (сняв или уменьшив техногенный фактор) примерно 15-30% суммарной дозовой нагрузки;

- за счет снятия на определенный период или замены медицинской рентгенологической диагностики на другие средства (УЗИ и т.п.) можно убрать до 25-30% суммарной дозовой нагрузки:

- при исходном низком естественном фоне и используя выше обозначенные принципы, можно для ограниченной части населения применять не только основной предел дозы (1 мЗв/год), но и вспомогательный предел (5 мЗв/год).

Знание экологической нормы естественного фона, динамики изменения радиационной обстановки во времени, а также создание специальных регламентов жизнеобеспечения и жизнедеятельности человека на загрязненных территориях позволяют уточнить величину вспомогательного предела дозы и длительность его применения с целью недопущения нарушения самых жестких нормативов МКРЗ, а именно, превышения на протяжении всей жизни годовой эффективной эквивалентной дозы - основного предела - 1 мЗв в год.

Например, имеется район, в котором превышение среднегодовой эквивалентной эффективной дозы над техногенным и медицинским фоном по внешнему и внутреннему облучению составляет 2,5 мЗв.

Рекомендации: использовать все резервы лимита радиационных нагрузок (уточнение фона, создание радиационно-чистого жилья, места работы, питания, отмена на определенный период рентгенодиагностических исследований, замена их на УЗИ, цикл оздоровления в чистой зоне, выезд на 2 месяца из зоны и т.п.).

Из этих же примеров и обобщений следует, что с точки зрения современных эколого-физиологических и эколого-радиационных подходов не могут быть единые нормы радиационных показателей (их типичных величин) для всего земного сообщества. Если они и рекомендуются, то могут быть приняты как чисто ориентировочные и, к сожалению, мало информативные в плане создания конкретных систем жизнеобеспечения как в обычных условиях, так и после крупных эколого-радиационных катастроф.

Перспективы развития и запросы современной науки состоят в создании и разработке региональных нормативов естественных фоновых экологических показателей (включая и радиационную компоненту), определении техногенных радиационных и других "наслоений" и, наконец, самое главное - в разработке методологии и нормативов допустимых радиационных рисков с точки зрения адаптивных возможностей организма человека и животных, приспособившихся для жизнедеятельности в определенной природной зоне (экологической нише).

Приведенные аргументы указывают на необходимость получения фундаментальных базовых данных об экологии человека и среды обитания для создания систем жизнеобеспечения в сложном техногенном мире. Они также свидетельствуют о том, что с точки зрения эколого-физиологического нормирования действующего природно-экологического фактора на организм величины естественного радиационного фона, техногенно-усиленного фона и медицинской радиационной надбавки должны включаться в величину основного и вспомогательного предела годовой дозовой нагрузки.

Предложена новая концепция создания систем жизнеобеспечения на территориях, подвергшихся радиоактивному загрязнению, основной задачей которой является минимизация радиационных воздействий с учетом знаний для каждого конкретного места региональной нормы радиационного фона до аварии, техногенного фона, медицинской надбавки и прогноза дозовых нагрузок на перспективу. Минимизация радиационных нагрузок населения осуществляется за счет разумного оперирования ее составляющими компонентами, а также созданием особых регламентов жизнедеятельности на "грязных" территориях [5].

На примерах многих систем организма (эндокринная, сердечно-сосудистая, система крови и др.) показана специфика патофизиологического статуса детского и взрослого населения в послечернобыльский период. Акцентируется внимание на раке щитовидной железы у детей и особенностях его проявления за 9-летний период после аварии [6]. Показаны примеры нарушений здоровья детей на фоне других (кроме радиационного) техногенных факторов в экологически благополучных и экологически неблагополучных районах. Отмечена мультифакторность причин, влияющих на возникновение заболеваний, которые включают в себя, наряду с загрязнением окружающей среды, стрессовые состояния, бытовой и социальный дискомфорт населения.

Отмечается положительный опыт объединения усилий ученых Беларуси, России и Японии в плане оказания помощи пострадавшему населению. Используя принципы восстановительной медицины, в клиниках этих стран более четырех лет применялся комплекс оздоровительных мероприятий, включающий новейшие биоэнергетические и другие подходы. Продолжается совместный поиск средств фармакологической коррекции функциональных напряжений с использованием нейропептидов. Разрабатываются программы дальнейших совместных исследований.

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MEASUREMENTS OF THE CHERNOBYL ACCIDENT FALLOUT IN ISRAEL AND THE ASSESSMENT OF THE RADIATION DOSES TO THE POPULATION

XA9745864

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1. INTRODUCTION

Israel is located approximately 2000 km southeast of Chernobyl The fallout from the accident in Chernobyl reactor no. 4 on April 26, 1986 arrived in Israel on the night of May 2nd. Following the accident, studies of the radiological effects were initiated by many countries some of them many thousands of kilometers away[1 2]
These studies can be characterized by three periods.

a) First months following the accident - Measurements were taken to assess the immediate impact and to propose countermeasures that would reduce doses incurred by the population

b) First years following the accidents - Measurements were taken to validate that radiological effects are well below any regulatory limits, from both the fallout radioactivity in the country and import of food coming from other affected areas

c) The last years (e g 1990-1995) - Measurements were taken within the regular program of environmental radioactivity surveillance.

In this paper we have compiled the results of the studies in Israel which have followed the three phases mentioned above Assessment of the accumulated potential radiation doses to the population in Israel was made based on the results of those measurements covered in the three phases, considering the various possible pathways

2 FIRST MONTHS AFTER THE CHERNOBYL ACCIDENT[3,4]

Environmental monitoring to assess the Chernobyl accident fallout in Israel started on April 30, 1986 The radioactive cloud from the Chernobyl accident arrived in Israel on the night of May 2nd Measurements of radioactive air contamination, contamination

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b) First years following the accidents - Measurements were taken to validate that radiological effects are well below any regulatory limits, from both the fallout radioactivity in the country and import of food coming from other affected areas

c) The last years (e g 1990-1995) - Measurements were taken within the regular program of environmental radioactivity surveillance.

In this paper we have compiled the results of the studies in Israel which have followed the three phases mentioned above Assessment of the accumulated potential radiation doses to the population in Israel was made based on the results of those measurements covered in the three phases, considering the various possible pathways

2 FIRST MONTHS AFTER THE CHERNOBYL ACCIDENT[3,4]

Environmental monitoring to assess the Chernobyl accident fallout in Israel started on April 30, 1986 The radioactive cloud from the Chernobyl accident arrived in Israel on the night of May 2nd Measurements of radioactive air contamination, contamination

Table I: Air Concentration of Radioisotopes Related to the Chernobyl Accident as Measured in Yavne, Israel During May-July 1986

Sampling Period	Air Concentration (Bq/m^3)					
	$^{140}Ba/La$	^{103}Ru	^{137}Cs	^{134}Cs	^{132}I	^{131}I
30/4-2/5	(1)					
2/5-3/5						0.005
3/5-4/5	0.54	0.70	0.30	0.17	0.91	1.10
4/5-5/5	3.91	4.35	1.70	0.95	5.06	5.53
5/5-6/5	4.84	4.49	1.56	0.89	4.43	4.21
6/5-7/5	2.69	2.32	0.75	0.37	1.63	1.67
7/5-8/5	1.69	1.87	0.81	0.40	1.20	2.22
8/5-9/5	1.17	2.15	0.73	0.39	1.16	2.89
9/5-10/5	0.07		0.09	0.06	0.13	0.87
10/5-11/5	0.07	0.14	0.04	0.02	0.04	0.43
11/5-12/5	0.03	0.21	0.07	0.05	0.05	0.61
12/5-13/5		0.54	0.12	0.06	0.09	0.44
13/5-14/5	0.02	0.05	0.19	0.01	0.007	0.28
14/5-15/5	0.004	0.03	0.19	0.01	0.007	0.10
15/5-17/5	0.001	0.02	0.07	0.004	0.001	0.039
17/5-20/5	0.002	0.01	0.005	0.003		0.032
20/5-23/5	0.002	0.022	0.007	0.003		0.029
26/5-1/6	0.0007	0.023	0.004	0.002		0.006
1/6-9/6	0.0001	0.002	0.001	0.0005		0.001
9/6-15/6	0.0005		0.001	0.0006		0.0007
15/6-3/7		0.001	0.0005	0.0002		
3/7-30/7			0.0007	0.0004		

(1) Blank means less than 0.0001 for column 1 and less than 0.0005 for all other columns.

Table II: Several Results of the Measurements of Food, Water, Milk, Herbs etc. Taken from Various Points in Israel

Type of Measurements	Samples	Time Period (1986)							
		3/5	4/5	7/5	12/5	20/5	27/5	3/6	10/7
Water	Drinking Water (Bq/l)	--	--	--				--	
	Rain (Bq/l) (^{131}I)	2	63	96					
Milk	Cow Milk (Bq/l) (^{131}I)		--	--	--	15	7	2	
	Goat Milk (Bq/l) (^{131}I)		--	--	--	48		78	
Food	Tomatoes (Bq/Kg) (^{131}I)				63		3.7		
	Lettuce (Bq/Kg) (^{131}I)				610	450			
	Celery (leaves) (Bq/Kg) (^{131}I)				320				
	Strawberry (Bq/Kg) (^{131}I)				6				
	Meat (Bq/Kg) (^{137}Cs)				--			22	11
Herbs	Dill (Bq/Kg) (^{131}I)				2500		650		
	Parsley (Bq/Kg) (^{131}I)				1500				
	Thymin (Bq/Kg) (^{131}I)				1600		940		
Soil	Ground Contamination (Bq/m^2) SNRC (^{137}Cs)					420			
Grass	(^{137}Cs) (Bq/m^3)			600					
Assorted Leaves (Natural)	(^{131}I) (Bq/Kg)			1350	3450	2280	1920	540	80

-- Below detection limit.

Table III: Several Results of Milk and Thyroid Measurements and First Year Effective Dose Commitment to the Thyroid of an Average Adult

Time Period		Thyroid Gland (Bq/Kg)		Milk (Bq/Liter)				Thyroid Effective Dose[1]	
Year	Month	Adult	Goat	Cow ^{131}I	Cow ^{137}Cs	Goat ^{131}I	Goat ^{137}Cs	First Year (μSv)	
1986	2/5		20					Exposure Pathway	Dose
	9/5	155±11	42000					External (air)	0.35
	15/5	24-242	20000	12.6				External (ground)	5.0
	21/5	37-217	33000	15	4	48	9	Inhalation	110
	3/6		30000	2	--	78	23	Water	12.5
	4/7		6000					Food	217
	1/8		500					Milk	143
1987/88			<35					Meat & Dairy	113
1989/90			<35					Total	600

(1) The Thyroid effective dose for the different exposure pathways was assessed from the measurement results of Tables I, II and III.

-- Below detection limit.

Table IV: Several Results of the Measurements of Food and Air Samples Taken from Various Points in Israel in the second phase (after July 86)

Time Period		Ressusspended Fallout in Air [$\mu Bq/m^3$]			Radiocesium in Food [Bq/Kg]				
Year	Month	^{137}Cs	^{134}Cs	^{106}Ru	Bread	Milk	Poultry	Leafy Veg.	Fruit
1986	Aug.	778	300	240					
	Oct.	192	79	78					
	Dec.	150	68	67					
1987	Mar.	217	79	91					
	May	68	19	68					
	Jul.	47	12	--(1)					
	Sep.	44	12	--					
	Dec.	16	5	--					
1988	Jan.	41	15	--	6±2	1±0.2	3±0.5	5±1	4±1
	Mar.	40	11	--					
1989	July				<3	<2	<3	<6	<2

(1) Values denoted by (--) are below measurement threshold which was 4$\mu Bq/m^3$ for Cs and 40$\mu Bq/m^3$ for Ru with 20% uncertainty band.

Table V: Summary of the Potential Consequences to the Adult Population of Israel from the Chernobyl Accident Fallout (committed effective dose in microsievert for exposure during the time period)

Time period	Inhalation	External Radiation	Food and Drinks		Total (Estimated maximum)	Remarks
			Fruit & Veget.	Water & Milk		
May-July 1986 (1)	10	20	17	< 10	60	Center & North of Israel
	15	20	--	--	35	South Israel
April 1989 until March 1990					~10 (2)	
1994 and also 1995	--	8	2-4		12	--

(1) First Year effective dose commitments are shown.

(2) In our 1996 revision we found this value to be somewhat higher than in previous estimates[4].

of ground, rain and drinking water, grass and vegetation, food contamination including vegetables, fruit, milk, meat and herbs were performed for several months. The peak activity was recorded in air samples measurements between the 4th and 6th of May and has declined since. Table I shows the results of the measurements of six representative radioisotopes during the period May - July 1986.

The main results of the monitoring measurements made on water from wells and springs as well as from rainwater, ground contamination, milk, vegetation, herbs, meat and Thyroid glands, are summarized in Tables II and III for ^{131}Cs & ^{131}I. As can be seen, no contamination of drinking water was found above the detection limit of 0.7 Bq/liter. Considering this value for dose calculations an effective dose lower than 0.35μSv due to Iodine is obtained. Some contamination of up to 100 Bq/liter of ^{131}I was found in rain water collected from the rain that occurred on 3-4 and 6 of May. This rain had no measurable effect on the drinking water in the monitored wells and springs. The measured activity of food samples was also very low even though above detection limits. The first year effective dose commitment to the population from the fallout of the Chernobyl accident in Israel was calculated based on the above and other measurements. The results are summarized in Tables III and V. They show very low accumulated effective doses well below any internationally recommended action levels. Due to the relatively low levels of contamination found in air, water and foodstuff, no public health measures were advised or taken in Israel to limit consumption of locally produced food products. However, imported food was put under surveillance beginning mid-May with the following initial action levels:
250 Bq/Kg for ^{131}I and unidentified beta-gamma emitters.
500 Bq/liter for ^{131}I in milk.
600 Bq/Kg for ^{137}Cs and ^{134}Cs.
25 Bq/Kg for alpha emitters.
These systematic controls were lifted since 1990 from the import system. However, control samples are taken on a periodic basis until present, without noticeable results.

3. FIRST YEARS AFTER THE CHERNOBYL ACCIDENT

Following the first phase that ended July 1986, the studies of the environmental impact in Israel from the Chernobyl fallout continued, mainly by the Ministry of Health (now this division is part of the Ministry of the Environment) which funded the Soreq and Negev Research Centers of the IAEC to conduct the surveillance. Tables III and IV summarize the results of these measurements.

During this period the food import control revealed only very few cases of food contamination mainly in the case of nuts. As a general rule substantially contaminated food, even below action levels, was not accepted, and was ordered to be returned to the supplier.

4. THE RECENT YEARS OF ENVIRONMENTAL SURVEILLANCE

Measurements taken by the Ministry of the Environment in various regions in Israel in the years 1994 and 1995 indicate that the averages of regional Cs-137 soil concentrations vary from 1 to about 40 Bq/Kg (see fig. 1). It has been concluded that a value of 20 Bq/Kg can serve as a rather conservative value representing the average "national" Cs-137 soil concentration.

External doses to the "average member of the public" from Cs-137 deposited on the ground have been estimated, considering the distribution of Cs-137 with depth in soil (relaxation length of approximately 3cm) and an average shielding factor of 0.4 to account for indoor and outdoor occupancy[(5)].

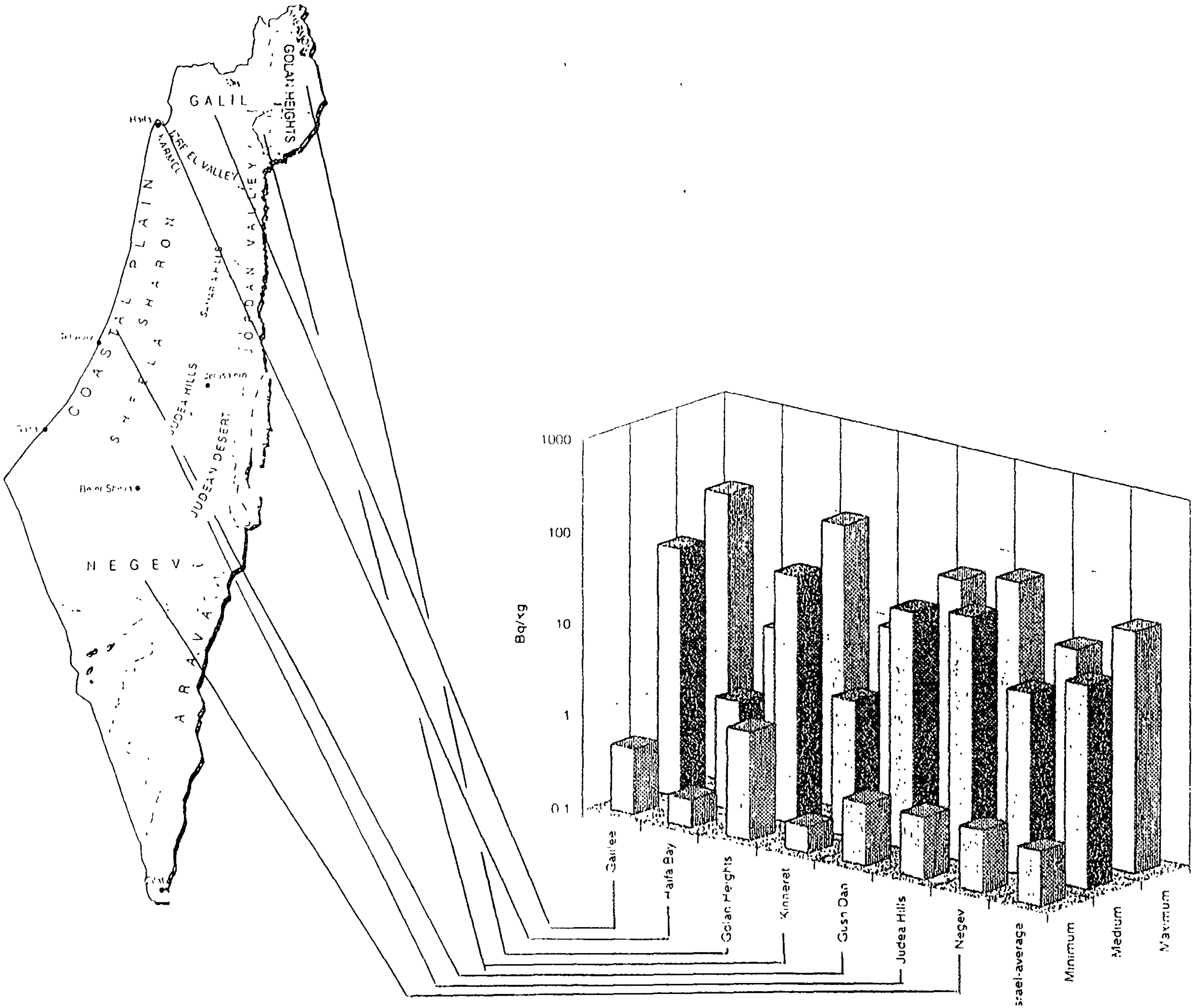

Fig 1 Cesium-137 distribution in Israel soil (1994-1995)

Considering these factors, a value of 5×10^{-4} μSv/h per kBq/m^2 has been used, which, for an average surface concentration of 2000 Bq/m^2 (corresponding to soil concentration of 20 Bq/Kg), gives an annual average individual dose of about 8 μSv.

Food contamination measurements taken in 1994-1995 were below detection limits. However, internal exposures resulting from food ingestion pathway have been theoretically estimated. Cs-137 soil-to-plant tranfer coefficients for various foodstuff categories have been adopted from ref. (6) as well as Israeli daily consumption values for each category. Using a value of 1.3×10^{-8} Sv/Bq ingested[(7)], a total annual ingestion dose of about 4 μSv to the "average member of the public" has been calculated. It should be emphasized, that these calculations can be considered rather conservative (especially regarding actual consumption rates and ignoring food import); A value of 2 μSv from ingestion may turn out to be more realistic.

Cs-137 concentrations in drinking water have also been found to be below detection limits. Considering volumes of drinking water resources in Israel, as well as continuous dilution processes, it may be concluded that annual doses from drinking water are significantly lower than external and internal doses from ground deposition and food consumption, respectively.

Based on the above assessment Table V summarizes our estimates of the potential consequences of the Chernobyl fallout to the adult population in Israel.

5. CONCLUSION

It can be concluded that the total annual effective dose given to the average member of the public in Israel from Cs-137 fallout resulting from the Chernobyl accident in the year 1995 does not exceed 12 μSv which is less than 0.5% of the average total individual exposures due to all radiation sources (natural background radiations including Radon and "man made" radiations including medical exposures). Also, the cummulative average individual dose given from the Chernobyl fallout during the period 1986-1996 is less than 10% of the total "background" exposures in a single year.

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MANAGEMENT OF RADIOACTIVE WASTE GENERATED BY THE CHERNOBYL ACCIDENT

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ОБРАЩЕНИЕ С РАДИОАКТИВНЫМИ ОТХОДАМИ, ОБРАЗОВАВШИМИСЯ ВСЛЕДСТВИИ ЧЕРНОБЫЛЬСКОЙ КАТАСТРОФЫ

Источниками образования и местами сосредоточения РАО в зоне отчуждения являются следующие обьекты

- объект "Укрытие",
- Чернобыльская АЭС,
- специально оборудованные пункты захоронения радиоактивных отходов (ПЗРО) ,
- пункты временной локализации радиоактивных отходов(ПВЛРО),
- природные обьекты,
- пункты спецобработки транспортных средств (ПУСО),
- производство по дезактивации оборудования, материалов и т п

Специфика отходов зоны отчуждения обусловлена

- большим количеством и разнообразием отходов их состава и активности,
- наличием в отходах альфа-излучателей,
- миграцией радионуклидов в окружающей среде

По данным инвентаризации на 1994г , в зоне выявлено 13 обьектов локализации РАО с обьемом хранения 100 млн м3 и суммарной активностью
0 42 млн Ки

В соответствии с "Концепцией зоны отчуждения" и "Национальной программой
ликвидации Чернобыльской катастрофы и социальной защиты граждан на 1994-95 г и на период до 2000 г " основная стратегическая задача по обращению с РАО в зоне отчуждения - минимизация вредного воздействия обьектов с РАО на окружающую среду с приведением в дальнейшем их в экологически безопасное состояние

Данная цель реализуется следующей схемой обращение с радиоактивными отходами зоны отчуждения

- Высокоактивные отходы, извлекаемые из объекта "Укрытие" и ПВЛРО, должны разделяться на топливосодержащие (ядерноопасные) и ядернобезопасные отходы

- Последующее контролируемое хранение контейнеров с высокоактивными отходами осуществляется в хранилищах поверхностного типа оснащенных системами перегрузки, контроля безопасности

- Отработавшее ядерное топливо ЧАЭС подлежит временному хранению в ХОЯТ-2 ЧАЭС, строительство которого предусматривается "Программой работ по снятию с эксплуатации ЧАЭС"

- Окончательное захоронение ВАО (возможно, и ОЯТ) должно осуществляться в условиях, обеспечивающих надежную изоляцию отходов от биосферы в течение десятков тысяч лет.

- С целью реализации программы обращения с высокоактивными отходами зоны отчуждения должны быть созданы:

- дополнительное хранилище отработанного ядерного топлива энергоблоков ЧАЭС,
- комплекс по сортировке и контейнеризации извлекаемых ВАО при проведении работ о выводу ЧАЭС из эксплуатации и переводу обьекта "Укрытие" в экологически безопасное состояние,
- промежуточное хранилище для кондиционированных высокоактивных отходов

- технические средства ведения работ по дистанционному извлечению ВАО из объекта "Укрытие" и ПЗРО и системы приборного контроля делящихся материалов.

- Низко- и среднеактивные отходы классифицируются по категориям на перерабатываемые и неподлежащие переработке

- Неперерабатываемые отходы направляются на захоронение в хранилища приповерхностного типа оборудованные системами перегрузки и контроля.

- Перерабатываемые отходы в транспортно-упаковочных комплектах поступают на технологические линии сжигания, прессования, усредненного переплава и цементирования

- Контейнера с переработанными отходами размещаются в хранилищах поверхностного типа оснащеных системами перегрузки, дренажного водоотведения , датчиками контроля состояния отходов.

- За отходами, находящимися в ПВЛРО осуществляется радиоэкологический мониторинг для принятия обоснованных решений по их дальнейшей стабилизации или перезахоронению

Предусматривается завершение работ по сооружению комплекса производств для переработки и длительного хранения и захоронения низко- и среднеактивных отходов зоны отчуждения, а также техническое оснащение создаваемого Центрального предприятия по переработке радиоактивных отходов АЭС.

На основании выводов и рекомендаций "Генеральной схемы развития отрасли обращения с РАО в Украине" и последующих технико-экономических расчетов предложена централизованная схема обращения с РАО

Она предусматривает строительство в Украине Центра переработки и захоронения (ЦПЗ) низко- и среднеактивных отходов промышленности (включая АЭС), медицинских, научно-исследовательских и других учреждений, а также РАО, образовавшихся в результате аварии на ЧАЭС в зоне отчуждения.

LONG TERM EFFECTS ON MINKS OF THE RADIATION FACTORS FROM THE CHERNOBYL ACCIDENT

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1. Structural and Functional Changes in Female Reproductive Organs That Reside in the Stage of Menopause and Fetus Embryogenesis. Ultrastructural and Electron-Histochemical Characteristic of Neurohormonal Regulatory System of Female Reproductive Function.

Introduction

The study of small radiation dose influence on human and animal reproductive functions becomes more and more topical after Chernobyl Nuclear Power Plant (ChNPP) accident. In the number of cases, animals that reside in continuos internal, as well as external exposure zone, have pregnancy interruption in its early stages (up to 30 days). This, without any doubts testifies for reproductive process disorder as a whole (hypophysis-ovary-uterus system) and also, as its separate links.

The important thing is that a break in any one of those links leads to pregnancy interruption. Hence, in order to determine any disorders in reproductive system functional state, profound and detailed morphofunctional study of the system links (accounting for radiation exposure factors) needs to be done. Because research in this field has just started, we were unable to find any material on this topic. There are, however, some references for morphofunctional changes of endocrine glands, hypophysis in particular [1], [2], [3], [4] and sex glands [5], [6], [8], refereed to small radiation doses.

It was determined by the authors on a light-optical level that small dose exposure (up to 50cGy) of part of hypophysis does not lead to any significant functional of morphofunctional changes. Only with exposure doses more than 300cGy on the anterior lobe of hypophysis, some small morphological changes took place. These are the changes in a number of secretory elements in cells with increase of acidophile and decrease of basophile cells. Out of dystrophic changes, protoplasm turbidness and nuclei piknosis in basophile cells have been reordered by the authors [4]. And only with large doses (more than 2,000cGy) significant destructive changes in hypophysis (secretory cell decay) took place [7]. The main objective of this research is morphofunctional study of structural and functional peculiarities of endocrine-reproductive animal system with low internal and external exposure doses. Also, the link of such changes with pregnant female's reproductive system disorders.

Materials and Methods:

As a part of the project we examined hypophysis, ovaries, and uterus in 10 pregnant females from Chernobyl zone, exposed to small internal, as well as external radiation doses. Also, control animal group (10 minks), with almost negligible radiation factors was studied. The examined females included the ones with normal and pathological pregnancy progression. Bioptates of hypophysis, ovary, and uterus were studied on light-optical, as well as on electron-microscopic levels. Ultrathin slices of 400-600Å were prepared on LKB and Reichert ultratoms. Stained according to Reinhold for contrast enhancement, slices were examined with EM-400T Phillips Electron Microscope. For accurate ultratoming and comprehensive pathological process' estimation, half-thin slices of 1500Å were prepared from the blocks jellied in epoxide resin and stained with toluede blue-peronine for microscopic examination.

Conclusion:

Complex histochemical, electron-microscopic, and electron-enzyme-histochemical examination of hypophysis, ovary, and uterus has been carried out. Purpose of the examination was to study morphofunctional state of endocrine-reproductive system accounting for extended internal and external small exposure doses from Chernobyl radioactive factors.

The results showed different dystrophic-destructive changes in cell elements and microcirculatory vascular channels that both lead to disorder of reproductive function and pregnancy interruption in females. Morphological changes in follicle-stimulating and luteinizing cells of adenohypophysis is a very good example of this.

During normal pregnancy progression, increase in morphofunctional activity with increased number and hypertrophy of secretory granules has been observed in many honadotropocytes on a background of high protein synthesis and energy generation of these cells. Females with pregnancy interruption had definitely lower morphofunctial activity of preponderant honadotropocytes. That is because in the most follicle stimulating honadotropocytes, absence or significant decrease in secretory granules was observed. These adenocytes had quite significant dystrophic-destructive changes in intercellular organelles due to decrease in protein synthesis and energy generation levels.

Detected changes need to be considered as the ones that depend upon radiation, because during normal pregnancy progression we have found follicle-stimulating and luteinizing cells with low secretory activity. Although they did not have significant dystrophic-destructive changes that cause cell morphofunctional state disorders. Not only honadotropocytes, but also other adenohypophysis' cells, dominating somatotropocytes in particular had destructive changes. This is an important model of adenohypophysis radioactive damage. Significant example of radiation effect on adenohypophysis ultrastructure is partial damage of its microcircular system. This results in blooding and expansion of intrabrainal capillaries accompanied by capillarostasis and destructive changes in endothelial bedding. In particular, in margnial part of endotheliocytes were most active metabolic processes between microvessels and adenohypophyse cells take place. Changes in endothelial cells were most specific for radiation effect presented as flatting of marginal part of endotheliocytes, plasmocytosis, and absence of micropinocytosic activity. As for morphofunctional changes in uterus with normal pregnancy progression and its interruption in females that reside in continuos radiation exposure zone, we were unable to find any specific changes due to radiation. We can only assume that revealed dystrophic-destructive changes in endometrium glandular epithelium cells, during pregnancy interruption were more significant than during normal pregnancy progression. Changes in microcircular vessels in both cases were the same. In ovary follicular epithelium it was almost impossible to differentiate changes due to follicle grow and differentiation from radioactive influence processes. In order to separate these processes, utilization of specific immunohistological and radioautographic methods of examination would probably be necessary.

Therefore, the conducted research had shown that most distinctive dystrophic-destructive changes in endocrine-reproductive function of Chernobyl zone pregnant females (with pregnancy interruptions involvement) have been observed in adenohypophysis' gonadotropic cells. According to the obtained morphological data, their structural-functional changes due to reproductive function damage, as well as radiation factor influence were detected.

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3. Embriogenesis' Peculiarities During long-time External and Internal Animal Irradiation.

Introduction:

The experiments on teratogenic and embriotoxic properties' detection of four generations of animals that for a long time resided in external and internal small dose irradiation zone have been carried out. For comparison purposes, a group of animals that resided in 'clean' areas was used.

The total number of animals used in experiment equals to 14. It includes 11 animals that resided in Chernobyl zone (9 females and 2 males) and 3 control animals. Mating was made one month before the experiment. Average Chernobyl zone female mass recorded to be 967+/- 32.5 g. At the same time average control female mass was 1132+/-45 g. Out of 9 examined females, one had no sign of pregnancy: ovarian yellow bodies and fetal sac were absent. This female had macroscopic pathological changes in internal organs such as lung and liver hemorrhage, bad heart, and a number of highly enlarged vessels in stomach. The rest of the animals (8 minks) generally had 90 ovarian yellow bodies and 39 fetal sacs that had 25 viable and 5 non-viable fetuses, rest of the sacs contained hemorrhagic fluid. Blood coagulation in all examined females was speeded up, giving the average of 12.43+/-3.8 sec. At the same time males had 135 sec. and control females - 160 sec. coagulation time. Pre-implantational fetus mortality of Chernobyl zone females was 56.7% and post-implantational - 35.9%. Control minks had pre-implantational fetus mortality equal to 33% which is quite normal for this group; post-implantational mortality was not observed at all: only 1 out of 30 embryos, which gives 3%.

Therefore, embryonic mortality analysis shows that female minks resided in Chernobyl zone had increased pre-implantational and post-implantational mortality. This proves for neuroendocrine regulation damage in female minks, accounting for environment factors. Pregnant inability in female is due to hormonal disbalance: hypophysis and hypothalamus primarily. Pre-implantational death can be caused by insufficiency of hypophysis' gonadotropic hormone lutropine, as well as progesterone. Post-implantational death is primarily due to progesterone deficient.

The average embryo number of studied group equals to 3.125+/-1.02. At the same time control animals had 9.7+/-0.33, that is three times less. The average embryo mass of studied group gives 6.8+/-1.07 and the mass of control embryos - 8.13+/-0.49. Embryos of both studied and control groups were deviled into two subgroups. First subgroup embryos were fixed in Byene fluid; after complete fixation 9 cuts were made for brain and intraorgan structure examination. Second group embryos were fixed in alcohol, lightened in KOH, and stained (bone tissue) by alizarin - red.

The results of the examination showed that ossification in studied and control group occurred similar. Although brain and intraorgan structures in studied group significantly differed from the controls. Big number of examined animals had brain, eye, liver, kidneys, lungs, and stomach hemorrhage along with epidural hematomas; sometimes, pleural cavity and intramuscular hemorrhage. Hence, the conducted research show a number of changes in animals that resided in superior environmental factor areas.

Environmental factor influence of mink embryonic mortality

Female minks that resided in Chernobyl zone

animal #	yellow body	fetal sac	viable fetuses	non-viable
1	-	-	-	-
2	14	11	4	1
3	13	11	8	3
4	15	-	-	-
5	14	4	5	-
6	10	1	-	-
7	14	3	4	-
8	9	4	-	-
9	11	5	4	1
TOTAL:	100	39	25	5

Female minks that resided in "clean" areas.

1c	14	10	10	1
2c	16	11	10	1
3c	15	9	9	-
TOTAL:	45	30	29	2

These are:

- pregnancy absence
- 1/3 had pre-implantational embryo deaths
- implanted embryos had big macroscopic changes such as hemorrhage and bleeding.

All these can possibly cause change in blood coagulation of pregnant females. The following data shows effects of residing in Chernobyl zone, accounting for internal and external irradiation of reproductive system and also, presence of macroscopic changes, such as bleeding and hemorrhage to different organs in studied group embryos.

4. The ChNPP Accident Radiation Factor Mutagenic Affection Study.

Introduction:

Objectives and type of the research first of all are determined by genetic-physiological peculiarities of animals. Different genotype mink cytogenetic study could possibly reveal those changes (on chromosome level) that accompany ionized radiation mutagenic influence. Such examinations could not only detect cytogenetic changes in different genotype minks, but also present material for future comparative study research of similar changes with time, depending upon the radiation dose.

Another set of problems, that need cytogenetic research methods, is due to embryonic mortality reasons. In this case it is very important to understand what is the role of lethal structure damages and chromosome number in prenatal deaths. Perhaps, study of chromosome anomalies' occurrence not only in sex, but also in somatic mink cells could possibly clear up the discussed problem [1].

It is known that normal diploid chromosome set damages are accompanied by distinct morphologic and physiological anomalies. Adequate function study of proliferative system is determination of cell distribution according to cellular cycle phases. As an experimental model we have chosen proliferative processes' activity phenomenon (aneuploidy and polyploidy) on different stages of cellular cycle. All intracellular structures get damaged due to radiation influence. Different reactions, division and DNA synthesis delays, along with membrane damages were detected in cells.

All these speaks for need in cytogenetic examinations, in particular for proliferative process activity study on different stages of cellular division. Such studying can significantly improve understanding of the process, help with radiation effect estimation.

Cytogenetic research was conducted by laser flowing cytoflourometry method and examinations of chromosome aberrations. The research has been carried out by using up-to-date methods: computers with (CellFIT-Analysis Results) software for estimation of DNA condition in bone marrow and peripheral blood lymphocytes of both humans and animals. All the equipment had undergone metrologic control in time.

Methods and Results:

For research we used minks from Chernobyl zone and Barishivka village. Dates for animal collection (May-November) on farms were the same as for their mortifying. For experimental purposes 10 clinically healthy minks were killed. The animals were mortified by injection of dose 1000 times the muscle relaxant one. Out of bone marrow cells obtained from thigh bones, chromosome preparations were made. Metaphase slides, good for cytogenetic examinations were also analyzed [2].

We examined bone marrow cells and peripheral blood lymphocytes of Letreola vision Brisson minks. Cell suspension was obtained by disperging, later re-suspended and filtered. Cell washing and centrifuging (g=300 rev/sec. for 5 min.) were made two times in Henks medium (pH=7.4). After that cells were fixed in 70% alcohol with medium. Right before cytogenetic analysis cell suspension was re-suspended and centrifuged for the second time (300 rev/sec. for 5 min.). To obtained sediment a fixing buffer was added according to Gacrson N., along with bromic ethidium of 10 E-7 mcg/ml final concentration. Cells were analyzed by I. Lefkovits method [3], using laser flowing cytoflourometer (FACStar Plus by Dickinson, USA). Argon laser was set to 488 nm wavelength with 250 mVt power. Average cell analysis speed equaled 500 cells/sec. Total of 10,000 cells were analyzed in every sample. After triton fixing, cell membranes were loaded with bromic ethidium, a fluorescent stainer that interacted with nucleus' DNA. Later on, this cell suspension had to be injected under pressure into analyzer's optical system.

Chromosome sample preparation was done according to generally accepted methods [5]. The results of the research had to undergo different statistical analysis in order to determine validity of changes between studied and control animals with 95% assurance level. For statistical data analysis IBM PS/2 (30,60) computers with "Statgraphics" and "Foxgraph" software were used.

Conclusion:

Our data shows that minks most frequently have some deviations in big [1-6] chromosomes and that another cases of aneuploidy involve medium and small chromosomes. With a half-year research we are yet unable to make some definite conclusions as for genetic damage significance of bone marrow imunocompetent tissues and peripheral blood lymphocytes of animals that reside near ChNPP. Cytogenetic bone marrow and peripheral blood cells' analysis showed that the exposed group had less percentage of cells in S-phase. At the same time an increase in G2-phase cells, if compared to controls, was observed. In other words, under small doses of ionized radiation influence, percentage of cells with intensive biosynthesis process, were energy accumulation takes place is going up. Causing, at the same time decrease in number of those cells where DNA replication and gystone synthesis (to which every DNA cell is connected) take place. The similar situation was observed in peripheral blood lymphocytes. Therefore, according to our and other scientists' data, chronic exposure with small radiation doses that is not the same for studied tissues can cause an increase in genetic instability [7].

This shows that those animals that were exposed with small radiation doses had less intensive reparation processes in tissues if compared to animals that resided in more or less radioactively clean areas. Taking into account the obtained data on number and type of genetic damages, one can assume that basis for the future development of diagnostic test (small doses of ionized radiation organism influence) has been found.

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XA9745867

FUNDAMENTAL PRINCIPLES FOR OBTAINING AGRICULTURAL PRODUCE OF STANDARD PURITY IN THOSE PARTS OF THE RUSSIAN FEDERATION WHICH WERE RADIOACTIVELY CONTAMINATED AS A RESULT OF THE CHERNOBYL ACCIDENT, AND THE EFFECTIVENESS OF THE MEASURES BEING TAKEN

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ОСНОВНЫЕ ПРИНЦИПЫ ПОЛУЧЕНИЯ НОРМАТИВНО ЧИСТОЙ СЕЛЬСКОХОЗЯЙСТВЕННОЙ ПРОДУКЦИИ НА ТЕРРИТОРИИ РФ, ПОДВЕРГШЕЙСЯ РАДИОАКТИВНОМУ ЗАГРЯЗНЕНИЮ В РЕЗУЛЬТАТЕ АВАРИИ НА ЧАЭС И ЭФФЕКТИВНОСТЬ ПРОВОДИМЫХ МЕРОПРИЯТИЙ

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When radiation accidents occure, accompanied by releases of radioactive substences into the environment and arable land contamination, the radionuclide intake to agroindustrial products results in an additional source of irradiation for man. For the decrease in radionuclide content in agricultural products a complex of countermeasures in plant and animal production should be carried out. The results from the investigations performed indicate that quarantined obtaining of high quality plant products may be achieved by optimisation of crop cultivation technology when qualitatively implementing all the agrotechnical operations and introducing the techniques facilitating the decrease of radionuclide transfer to plants. The use of agricultural ameliorants (vermiculite, bentonite), capable of non-exchanging radoinuclide absorption in soils, reduces the ^{137}Cs accumulation in yield from 1,5 to 3 times. This technique should be introduced when improving grass stands of forage lands on peaty soils where, due to low content of clay minerals, accumulation of radionuclides in grass yield is by a factor of 3-4 higher than on soddy-podzolic soils. The decline in the radionuclide concentration in plant products (up to 3 - fold) is achieved by a combined application of potash fertilisers and lime materials, especially on soils with low availability of exchangeble potassium and calcium. When cultivating agricultural crops in crop rotations, the soil treatment technology reduces the concentration of radionuclides in plant products. Deep boardless ploughning of soddy-podzolic sandy soils leads to the redistribution of up to 20% of ^{137}Cs beyond the ploughning horizon resulting in a two-fold decrease in radionuclide transfer to yield. One of the most resultative economically inexpensive techniques on arable and forage lands under conditions of radioactive contamination is a selection of the most productive crop species and varieties showing the minimum radionuclide accumulation. Specific distinction in ^{137}Cs accumulation may reach from 2 to 45 times. Variety distinction are less and

account for 2 to 5 times. The basis for obtaining plant products fully satisfactory for human consumption is a rational organisation of feed stuffs production, provision for animals of complete balanced diet with minimum radionuclide content, availability of high-productive animals. A significantly high effect was observed for the replacement of pasturing in summer by stabling-pasturing management, and incorporation into animal diet of grasses and crops with minimum accumulation of radionuclides. In recent years the animal husbandry practice actively, albeit restrictively, uses feed additives containing in ammonium-iron-hexacyanoferrates, resulting in a two-fold decrease in ^{137}Cs transfer to milk.

При радиационных авариях, которые сопровождаются выбросами радиоактивных веществ в окружающую среду и загрязнением сельскохозяйственных угодий, поступление радионуклидов в агропромышленную продукцию приводит к формированию дополнительного источника облучения человека. В противоположность внешнему облучению, ограничение воздействия которого экономически достаточно дорогостояще, регулирование внутреннего облучения, т.е. изменение поступления радионуклидов в организм человека с местными продуктами питания, рассматривается как реально достижимый способ снижения суммарных дозовых нагрузок на население.

Радиоактивному загрязнению после радиационной аварии на ЧАЭС подверглась значительная часть территории России. Наиболее сложная радиоэкологическая обстановка сложилась в районах Брянской (7 районов) и Калужской (3 района) областях.

В задачу наших исследований входило изучение влияния комплекса мероприятий (агротехнических, агрохимических, технологических, специальных и организационных) на качество продукции растениеводства и животноводства в условиях радиоактивного загрязнения сельскохозяйственных угодий и возможности производства продуктов питания с минимальным содержанием радионулидов.

Результаты проведенных нами исследований (1986-1990 гг.) показали, что проведение защитных мероприятий в растениеводстве (заглубленная вспашка, внесение повышенных доз фосфорных и калийных удобрений, известкование почв с pH ниже 5,0, коренное улучшение естественных кормовых угодий) позволили в большинстве хозяйств получать сельскохозяйственную продукцию, в том числе молоко и мясо, соответствующую установленным радиологическим стандартам. Но с течением времени после радиационной аварии на ЧАЭС требования Минздрава РФ к качеству продуктов питания, получаемых на радиоактивно загрязненных угодьях, ужесточаются. Уменьшение содержания радионуклидов в продукции растениеводства и живтноводства является важнейшим фактором, позволяющим обеспечить безопасное проживание на загрязненных территориях сотен тысяч людей, путем целенаправленного снижения дозы внутреннего облучения.

В практике землепользования во всех почвенно-климатических зонах России, пострадавших от радиационной аварии на ЧАЭС, отдавали предпочтение мероприятиям, проведение которых не требует существенного изменения применяемой технологии возделывания сельскохозяйственных культур и коренной перестройки севооборотов, традиционных для данной территории.

На радиоактивно загрязненных сельскохозяйственных угодьях возрастает роль севооборотов в снижении перехода радионуклидов из почвы в растения и миграции по трофической цепочке: почва-растения (корм)-животные-продукция животноводства. Так, содержание ^{137}Cs в зерне озимой ржи, возделываемой по овсяно-бобовой смеси на зеленый корм в 3 раза ниже, чем в урожае растений, выращиваемых после люпина и сераделлы. При возделывании озимой ржи в зерно-травяном севообороте на дерново- подзолистой песчаной почве при 40% насыщенности зернобобовыми культурами ^{137}Cs в зерне накапливается в 6-7 раз больше, чем в севооборотах, где площадь под люпином и сераделлой составляет 10-15%.

Поступление радионуклидов в растения и накопление их в урожае заметно варьирует в зависимости от кислотности почвенного раствора, механического и минералогического состава, емкости поглощения, содержания гумуса и его качественного состава, степени насыщенности почв основаниями, физико-химических свойств радионуклидов, агротехники возделывания сельскохозяйственных культур, агрометеорологических условий внешней среды. Нейтрализация кислотности почвенного раствора на всех типах почв в зоне радиоактивного загрязнения уменьшает накопление ^{137}Cs и ^{90}Sr в урожае зерновых культур и злаковом сене в 2-3 раза.

При возделывании сельскохозяйственных культур в полевых и кормовых севооборотах на дерново-подзолистых почвах с низким содержанием гумуса и элементов минерального питания растений чередование культур должно быть направлено на пополнение запасов органического вещества и создание положительного азотного баланса этих почв. Внесение органических удобрений (навоз, ТНК в дозе 40-80 т/га) и миниральных удобрений в оптимальных дозах снижает накопление ^{137}Cs в урожае зерновых культур и картофеля в 2-4 раза.

Существенное снижение концентрации радионуклидов в продукции растениеводства достигается при совместном внесении калийных удобрений и известковых материалов, особенно на почвах с низкой обеспеченностью обменным калием и кальцием. Применение калийных удобрений на фоне $N_{90}P_{60}K_{90}$ и материалов (эпсомит, доломитовая мука, известняковая мука) при возделывании озимой ржи, овса, люпина в смеси с рапсом в зерно-травяном севообороте уменьшает накопление ^{137}Cs в урожае в 1,4-3 раза. Наибольший положительный эффект в ограничении перехода ^{137}Cs в продукцию растениеводства отмечается при возделывании сельскохозяйственных культур на дерново-подзолистой песчаной почве при внесении $N_{90}P_{60}K_{90-120}$ и известковых материалов, содержащих магний.

Внесение высоких доз азотных удобрений, особенно при несбалансированном соотношении N:P:K в почвах, снижает качество получаемой сельскохозяйственной продукции, так как переход ^{137}Cs в растения заметно повышается.

Использование минеральных удобрений - одного из традиционных в растениеводстве приемов получения стабильно высоких урожаев - позволяет регулировать содержание радионуклидов в продуктах питания, особенно на дерново-подзолистых почвах.

При возделывании сельскохозяйственных культур в севооборотах технология обработки почвы позволяет уменьшить концентрацию радионуклидов в продукции растениеводства. Содержание ^{137}Cs в зерне ячменя и озимой ржи, в клубнях картофеля при обработке зяби дисковыми боронами и вспашке с полным оборотом пласта практически одинаково. Глубокое безотвальное рыхление дерново-подзолистой песчаной почвы приводит к удалению за пределы пахотного слоя до 17-20% ^{137}Cs, что снижает переход радионуклида в урожай ячменя, озимой ржи и картофеля в 2-2,3 раза (табл. I).

При перезалужении выродившихся сеянных травостоев и коренном улучшении естественных кормовых угодий обработка почвы и тщательное разрушение дернины позволяет снизить концентрацию радионуклидов в лугопастбищной растительности в 1,5-4,3 раза (табл. II). При разрушении дернины на суходольном лугу фрезерованием накопление ^{137}Cs в злаковом травостое снижается в 1,5 раза.

Вспашка плугом с полным оборотом пласта на глубину 20-22 см с последующим дискованием ограничивает переход ^{137}Cs в луговую растительность в 2,5 раза. Комбинированная обработка дернины и почвы при коренном улучшении суходольного луга с использованием серийно-выпускаемых сельскохозяйственных машин и орудий снижает содержание ^{137}Cs в злаковом сене в 4,3 раза. При коренном улучшении суходольного луга было внесено $N_{90}P_{60}K_{120}$.

Результаты проведенных нами исследований свидетельствуют о том, что гарантированное получение доброкачественной продукции растениеводства достигается оптимизацией технологий возделывания сельскохозяйственных культур, при качественном выполнении всех агротехнических операций и внедрением приемов, способствующих снижению перехода радионуклидов в растения. Применение агромелиорантов, способных к не-

Таблица I.

Содержание ^{137}Cs в урожае сельскохозяйственных культур (Бк/кг) при плотности загрязнения дерново-подзолистой песчаной почвы 1 кБк/м2

Способ обработки	Ячмень, зерно	Оз. Рожь, зерно	Картофель, клубни	Кукуруза, зел. масса
Вспашка (20-22 см)	0,057	0,051	0,075	0,030
Дискование (8-10 см)	0,050	0,049	0,067	0,032
Глубокое безотвальное рыхление (чизель -плуг)(40-45 см)	0,028	0,023	0,033	0,031
$НСР_{0,95}$	0,004	0,004	0,007	0,004

Таблица II

Влияние способа обработки почвы суходольного луга на накоп ление ^{137}Cs в злаковом травостое

Способ обработки	КП ^{137}Cs, (Бк/кг массы растений)/ кБк/м^2
Контроль (без обработки)	2,44 ± 0,48
Фрезерование в 2 следа	1,66 ± 0,24
Вспашка плугом на глубину 20-22 см	0,95 ± 0,11
Комбинированная обработка (фрезерование дернины в 2 следа, вспашка на глубину 20-22 см)	0,56 ± 0,08

обменной сорбции ^{137}Cs и ^{90}Sr в почвах, в кормовом севообороте снижает накопление ^{137}Cs в урожае трав в 1,5-5 раз (табл. III) по сравнению с контролем. Этот прием необходимо внедрять при улучшении травостоев кормовых угодий на торфяных почвах, где из-за низкого содержания глинистых минералов, которые переводят ^{137}Cs в труднодоступное для корневых систем состояние, накопление радионуклида в урожае трав в 3-4 раза выше, чем на дерново-подзолистых.

Таблица III

Содержание ^{137}Cs в злаковом травостое на дерново-подзолистой песчаной почве суходольного луга

N N Варианты п/п	Урожай воздушно-сухой массы, ц/га	Бк/кг воздушно-сухой массы растений	КП, ^{137}Cs (Бк/кг масс.растен.)/ кБк/м2
1. Контроль	17,4	971±80	1,57
2. Бифеж	27,8	260±25	0,45
3. $N_{90}P_{60}K_{90}Mg_{30}$	39,8	536±42	0,45
4. $N_{90}P_{60}K_{90}Mg_{30}$+ бифеж	42,8	157±12	0,30

Размещение сельскохозяйственных культур в полях севооборотов в зависимости от уровня радиоактивного загрязнения и проведение комплекса агротехнических и агрохимических приемов позволило снизить в Брянской области в 1990 г. производство зерна, загрязненного радионуклидами выше установленного радиологического уровня до 1% от объема закупок, сена многолетних трав до 16%, травяной муки до 4% и силоса до 1% от объема заготовок. В последующие годы в Брянской области содержание ^{137}Cs в продовольственном и фуражном зерне, картофеле и овощах значительно ниже ВДУ-91.

Одним из наиболее результативных приемов, экономически недорогостоящим, на пахотных и кормовых угодьях в условиях радиоактивного загрязнения является подбор наиболее эффективных видов и сортов культур, характеризующихся минимальным накоплением радионуклидов. При одинаковых условиях возделывания культур в севооборотах различия в накоплении ^{137}Cs в урожае в зависимости от вида достигают 3-4 раз. Исследования по изучению влияния сортовых особенностей на поступление ^{137}Cs в растения свидетельствуют о том, что эти различия составляют 2,5-7 раз (табл. IV).

Получение доброкачественной продукции животноводства в условиях радиоактивного загрязнения может быть решено двумя путями:

Таблица IV

Содержание ^{137}Cs в урожае различных сельскохозяйственных культур на дерново-подзолистой почве

Культура	Сорт	КП ^{137}Cs (Бк/кг массы продукц.)/ кБк/м^2
Озимая рожь, зерно	Новозыбковская-150	0,040
	Вересень	0,080
	Пуховчанка	0,037
Ячмень, зерно	Роланд	0,025
	Зазерский	0,050
	Московский-2	0,200
Овес, зерно	Буг	0,076
	Астор	0,116
	Скакун	0,140
	Эрдграф	0,300
Картофель, клубни	Полесский розовый	0,034
	Невский	0,045
	Резерв	0,012

внедрением и усовершенствованием интенсивной системы ведения животноводства;

применением специальных средств (препаратов), снижающих поступление загрязнителей в продукцию животноводства (молоко, мясо).

Основой получения продукции животноводства, полностью пригодной в пищу человека, служит рациональная организация кормопроизводства, обеспечение животных полноценными, сбалансированными рационами с минимальным содержанием радионуклидов, наличие в хозяйстве высокопродуктивных животных.

Оценка перехода ^{137}Cs по трофической цепочке почва-растения (корм)-рацион животных-молоко, проведенная в первые годы после аварии в хозяйствах с различной плотностью загрязнения ^{137}Cs, показала, что концентрация ^{137}Cs в молоке лактирующих коров летом 1987 года превышала ВДУ в 8-18 раз. При выпасе коров на естественных неулучшенных сенокосах через 3 года после аварии содержание ^{137}Cs в молоке превышало установленные радиологические нормативы в 3-7 раз и молоко в цельном виде для пищевых целей не использовалось.

Поверхностное улучшение пойменных и низинных лугов (внесение удобрений, подсев трав) снижает накопление ^{137}Cs в лугопастбищной растительности в 2,5 раза (колхоз им. Ленина, Клинцовского района), что позволило получить молоко, соответствующее радиологическому стандарту.

Коренное улучшение суходольных лугов, особенно вспашка комбинированными плугами, залужение с использованием агрегатов АПР-2,6 и АЗ-2,4 снижает накопление ^{137}Cs в лугопастбищной растительности в 1,5-11 раз (табл. V). Ведущая роль в уменьшении

поступления ^{137}Cs в растения при создании сеяных травостоев на естественных кормовых угодьях принадлежит минеральным удобрениям, особенно содержащих питательный элемент, недостаток которого ограничивает урожай трав на данной почве.

Таблица V

Накопление ^{137}Cs злаковыми травами при коренном улучшении естественных кормовых угодий (Брянская область), КП ^{137}Cs, (Бк/кг)/(кБк/м²)

Почва, угодье	Удобрения	^{137}Cs, Бк/кг воздушно-сухой массы растений	КП
Колхоз "Родина", Новозыбковский район			
Дерново-подзолистая супесчаная, суходольный луг	Улучшениене проводили	1760±94	2,66
	Вспашка, $CaCO_3$ (1Hг)+$N_{90}P_{120}K_{180}$	244±20	0,38
	Вспашка, $CaCO_3$ (1Hг)+$N_{90}P_{120}K_{240}$	157±16	0,23
Новозыбковский филиал ВИУА			
Пойменная дерновая, пастбище	Коренное улучшение проводилось в 1988 году	4800±250	4,71
	Вспашка, $N_{90}P_{60}K_{90}$	990±120	1,12
	Вспашка, $N_{90}P_{60}K_{90}$+Mg_{30}	610±40	0,72
Дерново-подзолистая песчаная, перезалужение суходольного луга	$N_{90}P_{60}K_{90}$	580±22	0,76
	$N_{90}P_{120}K_{90}$	410±16	0,62
	$N_{90}P_{120}K_{120}$	225±18	0,25
	$N_{90}P_{120}K_{180}$	180±11	0,27
Колхоз "Маяк", Злынковский район			
Осушенный торфяник	Улучшение не проводили	4250±102	7,10
	Вспашка, $N_{60}P_{90}K_{120}$	368±28	0,67

Значительное количество радиоцезия (до 60%) накапливается в нижнем ярусе (0-5 см) фитоценоза (табл. VI). При стравливании травостоя высотой 8-10 см поступление ^{137}Cs в организм животным с рационом снижается в 2-3 раза по сравнению с выпасом на малопродуктивном, низкорослом пастбище.

Учитывая достаточно широкие видовые и сортовые различия в накоплении ^{137}Cs и ^{90}Sr кормовыми культурами из почвы при составлении кормовых рационов можно выбрать растения, характеризующие меньшим накоплением радионуклидов. При выращивании и откорме свиней рационы с преобладанием картофеля и корнеплодом (до 50%) позволяют получать свинину в 5-10 раз менее загрязняющую, чем мясо крупного рогатого скота и овец. Существенно можно изменить концентрацию ^{137}Cs в мясе крупного рогатого скота за счет подбора кормов в рационе и изменения способа их содержания. При одинаковой плотности загрязнения почвы ^{137}Cs концентрация радионуклида в мышцах животных при содержании их на естественных пастбищах в 30 раз выше, чем при кормлении животных кормами, выращенными на пашне.

Концентрация ^{137}Cs в мышечной ткани сельскохозяйственных животных снижается в 10 раз при переводе их на кормление "чистыми" кормами за 2 месяца до убоя.

Для получения продукции животноводства с минимальным содержанием радионуклидов при ведении личных подсобных хозяйств на радиоактивно загрязненных территориях необходимо обеспечить животных "чистыми" кормами, заготовленными на пахотных угодьях или мелиорированных лугах. Но в отдельных ситуациях (отсутствие возможности создания культурных пастбищ и сенокосов на торфяных и сильноувлажненных минеральных почвах) получение "чистой" продукции животноводства затруднено.

Таблица VI

Содержание ^{137}Cs в травостое улучшенных и естественных лугов (Бк/кг воздушно-сухой массы)

Травостой	Высота травостоя, см от поверхности почвы				
	0-1,5	1,5-3	3-5	5-10	>10
Естественный травостой, пастбище	4736	2194	1103	851	788
Костер безостый, овсяница луговая	916	364	110	100	41
Мятлик луговой, ежа сборная	1651	922	777	571	416
Подсев ежи сборной в дернину	7117	1212	645	516	321

В этих условиях размеры перехода ^{137}Cs из загрязненного корма в продукцию животноводства можно уменьшить путем его сорбции в желудочно-кишечном тракте специальными средствами (добавлением в рацион или введением в организм животных сорбентов, химических соединений и лекарственных препаратов). В качестве таких средств могут быть рекомендованы ферроцианидсодержащие препараты (ФЦП): бифеж (целлюлозно-неорганическая композиция, полученная путем осаждения ферроцианида железа-калия на целлюлозном носителе), берлинская лазурь в виде болюсов (лекарственная форма), чистых порошок ферроцина и болюсов, соли-лизунца, сорбентов (тонкоизмельченный вермикулит, бентонит). В многолетних исследованиях (1990-1994 гг.) в хозяйствах Брянской области на всех видах сельскохозяйственных животных (молочный и мясной крупный рогатый скот, овцы, свиньи) получена высокая эффективность применения ФЦП для снижения перехода радиоцезия в продукцию животноводства. Концентрация ^{137}Cs в молоке через 6 суток после введения коровам болюсов берлинской лазури снижается в 3 раза. Применение берлинской лазури через 21 день после введения животным снижает концентрацию ^{137}Cs в мышечной ткани в 7,5-15 раз. Добавление в рацион животных сорбентов (тонкоразмолотой местной глины) способствовало двукратному снижению поступления ^{137}Cs в молоко коров (табл. VII).

Кратность снижения перехода радиоцезия в молоко при использовании бифежа и порошка ферроцина составляла 6-10 раз, болюсов - 1.5-2 раза, соли-лизунца до 1,4 раза.

Установлено, что оптимальными являются дозы для молочного скота: бифеж - 40-60 г., ферроцин 3-5 г на голову, болюсы по 3 шт. на голову через каждые 2,5-3,0 мес., соль-лизунец в виде брикетов с содержанием 10% ферроцина из расчета 20-30 г соли на голову.

Таблица VII

Влияние добавок глины в рацион коров на поступление ^{137}Cs в молоко (Бк/л)

Группы животных	Добавка глины в рацион, г	Сутки					
		0	1	2	3	5	10
1	контроль	1480±74	1517±67	1480±111	1480±111	1406±120	1517±74
2	200	1517±67	1369±71	1258±148	1147±74	1147±64	1184±84
3	400	1480±77	1332±72	1184±145	962±111	962±89	962±55
4	600	1443±120	851±111	777±74	740±67	703±55	777±74

Результаты проведенных исследований свидетельствуют о том, что получение доброкачественной продукции растениеводства и животноводства на радиоактивно загрязненной территории гарантируется при проведении защитных мероприятий в земледелии, высокой агротехнике возделывания сельскохозяйственных культур, поверхностном и коренном улучшении травостоя природных лугов, интенсивной системе ведения животноводства и использовании ферроцинсодержащих препаратов в рационе животных.

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RESULTS OF RADIOLOGICAL STUDIES OF WATER AND LAND ANIMALS IN NATURAL ECOSYSTEMS FOLLOWING THE CHERNOBYL ACCIDENT

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ИТОГИ ИССЛЕДОВАНИЙ ПО РАДИОЛОГИИ ВОДНЫХ И НАЗЕМНЫХ ЖИВОТНЫХ В ЕСТЕСТВЕННЫХ ЭКОСИСТЕМАХ ПОСЛЕ АВАРИИ НА ЧАЭС

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С момента аварии на Чернобыльской АЭС до настоящего времени Комплексная радиоэкологическая экспедиция Российской академии наук проводит оценку воздействия радиоактивного загрязнения на естественные экосистемы.

Радиоэкологический мониторинг водоемов, загрязненных в результате аварии на Чернобыльской АЭС, проведенный в 1986 - 1995 гг. экспедицией, выявил, что радиационный фактор в водоемах 30-ти км зоны, Киевском водохранилище, реках и озерах Брянской области не оказал значительного воздействия на гидробионтов на популяционном уровне.

Экспериментальные работы 1989-1992 гг. на пруду-охладителе ЧАЭС по оценке состояния воспроизводительной системы рыб, обитающих в условиях повышенного внешнего и внутреннего облучения выявили, что среди экспериментальных рыб более часто, чем в контроле, встречаются стерильные особи, а также рыбы, имеющие анамалии в развитии половой системы. Суммарная доза облучения, равная 8-9 Гр, не привела к полному поражению воспроизводительной системы рыб. В результате искусственного размножения (на примере белого толстолобика) были получены способные к размножению особи первого и второго поколений.

Концентрация Cs-137 в мышцах хищных рыб из Киевского водохранилища снизилась с 1500-2000 Бк/кг сырого веса в 1987 г. до 200-400 Бк/кг сырого веса в 1995 г. Учитывая, что концентрация радионуклидов в мясе рыб ниже 600 Бк/кг сырого веса, т.е. не превышает ПДК для пищевых продуктов, промысел рыбы в

Киевском водохранилище, а также в реках Брянской области в настоящее время не представляет опасности для здоровья местного населения.

В то же время, в ряде замкнутых озер Брянской области процесс снижения концентрации радиоцезия из-за гидрохимических условий происходит крайне медленно.

Например, в оз.Кожановское, расположенном в России на расстоянии 400 км от ЧАЭС, концентрация радиоцезия в мышцах мирных рыб в 1995 г. составляла 15 кБк/кг, у хищных рыб - до 42 кБк/кг сырого веса. В подобных водоемах необходимо продолжить радиоэкологический мониторинг и осуществлять запрет на промысел рыбы.

После аварии не были зарегистрированы факты гибели или миграции наземных позвоночных животных под прямым действием ионизирующей радиации. Исходя из мощности доз, имевших место на наиболее загрязненных участках вблизи станции, можно предположить, что часть животных, индивидуальные участки которых находились во время аварии в непосредственной близости от ЧАЭС, например, в "рыжем лесу", могли погибнуть.

В острый период, на всех участках 30-км зоны, где проводились исследования наземных экосистем, наблюдалось интенсивное размножение мышевидных грызунов, которое шло в основном за счет половозрелых сеголеток. У животных на наиболее загрязненных участках было зарегистрировано увеличение числа овулирующих яйцеклеток, но в то же время это увеличение сопровождалось значительной эмбриональной смертностью.

В половой структуре популяций мышевидных грызунов не произошло никаких изменений и примерное соотношение 1:1 самцов и самок сохранилось.

В первые годы после аварии при изучении различных органов и тканей животных были отмечены различные нарушения, частота встречаемости которых со временем постепенно снижалась, в то же время популяционные показатели изменялись в пределах нормы.

Для основной массы диких наземных позвоночных животных не отмечено угнетающего действия тех доз ионизирующей радиации, которые сформировались в результате аварии на ЧАЭС.

Прекращение хозяйственной деятельности на загрязненных территориях привело к сукцессии ряда биогеоценозов, что в свою очередь вызвало изменения в фауне и численности животных.

MAIN RESULTS OF THE TEN-YEAR STUDIES OF THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT IN TERMS OF THE RADIOACTIVE CONTAMINATION OF THE ENVIRONMENT

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The paper briefli describes issues related to dispersal of radioactive contamination after the Chernobyl accident. More detailed consideration is given to results of the recent studies (1991-1995) of the environmental contamination with principal dose-forming isotopes: Cs-137,Sr-90,Pt-239,240 in Russian Federation.The contamination of the surface air and depositions in the Central European part of Russia (EPR), South-West EPR and South EPR as well as in separate populated points and water bodies are discussed.Main tasks to be performed in 1996-2000 have also been formulated.

ОСНОВНЫЕ РЕЗУЛЬТАТЫ КОМПЛЕКСА ДЕСЯТИЛЕТНИХ ИССЛЕДОВАНИЙ ПОСЛЕДСТВИЙ ЧЕРНОБЫЛЬСКОЙ АВАРИИ ДЛЯ РАДИОАКТИВНОГО ЗАГРЯЗНЕНИЯ ОКРУЖАЮЩЕЙ СРЕДЫ

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Введение.

Информация о состоянии радиоактивного загрязнения природной среды в результате Чернобыльской аварии, полученная в 1986-1990 г.г. многими организациями различных ведомств в том числе в Институте экспериментальной метеорологии НПО "Тайфун" Росгидромета показала, что картина распределения радионуклидов, обусловленная многими причинами (действие источника, метеорологические процессы и др.) является весьма сложной.

Не останавливаясь в коротком сообщении на причинах "пятнистой" структуры полей радиоактивного загрязнения, механизмах перераспределения радионуклидов в компонентах окружающей среды, проблеме восстановления загрязнения окружающей среды йодом-131 (в том числе на основании анализа соотношений цезия-137 /йод-131) и др. [1-4] основное внимание сосредоточим на картине загрязнения природной среды Российской Федерации основными дозообрабатывающими изотопами цезием-137, стронцием-90, плутонием-239,240 сложившиеся в 1991-1995 г.г.

1. Приземная атмосфера и атмосферные выпадения.

Пункты наблюдения за концентрацией радиоактивных веществ в приземном слое атмосферы и их атмосферными выпадениями были организованы до аварии на ЧАЭС. Они входят в состав единой радиометрической сети Росгидромета, основной задачей которой является контроль за радиоактивным загрязнением окружающей среды на территории страны, обусловленным как нормальной работой, так и аварийными ситуациями на любых радиационно-опасных объектах

Для получения обобщенной картины загрязнения приземной атмосферы пункты наблюдения за концентрацией радиоактивных продуктов в воздухе на Европейской территории России (ЕТР) были сгруппированы по следующей схеме.

1 Центр ЕТР	Нижний Новгород, Самара, Обнинск, Ельня, Москва, Рязань, Воронеж
2. Юго-запад ЕТР	Курск, Брянск
3. Юг ЕТР	Астрахань, Волгоград, Ростов-на-Дону, Цимлянск

Пункты наблюдения за атмосферными выпадениями радиоактивных продуктов были сгруппированы следующим образом:

1. Центр ЕТР. Пункты, входящие в состав областей: Московской, Калининской, Смоленской. Пункты, относящиеся к Верхне-Волжскому и Приволжскому УГМС.

2 Юго-запад ЕТР Тула, Узловая, Вилово, Ефремово, Плавск **(Тульская обл.)** ; Брянск, Карачев, Красная гора, Трубчевск, Павля(Брянская обл.), Фатеж (Курская обл); Орел, Болхов, Дм.Орловской, Мценск, Верховье (Орловская обл.), Жиздра (Калужская обл.).

3. Юг ЕТР. Пункты, относящиеся к Северо-Кавказскому УГМС.

Результаты наблюдений за концентрациями в приземной атмосфере и атмосферными выпадениями радионуклидов в 1991-1995 г.г. представлены в табл.1.1-1.3

Таблица 1.1

Среднегодовые концентрации цезия-137 и стронция-90 в приземной атмосфере, 10^{-5} Бк/$м^3$

Территория	1991 г.		1992 г.		1993 г.		1994 г.		1995 г.	
	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90	Cs-137	Sr-90
Центр ЕТР	0,20	0,02	0,24	0,025	0,17	0,012	0,15	0,012	~0,2	~0,01
Юго-запад ЕТР	1,6	0,14	0,88	0,041	0,47	0,012	0,24	0,022	~0,2	~0,02
Юг ЕТР	0,40	0,08	0,30	0,022	0,22	0,017	0,23	0,030	~0,2	~0,02

Таблица 1.2

Среднегодовые концентрации плутония-239,240 в воздухе в Обнинске и Брянске, 10^{-8} Бк/$м^3$

Город	1992 г.	1993 г.	1994 г.	1995 г.
Обнинск	3,8	2,7	1,1	~1
Брянск	2,4	2,3	0,08	~1

Таблица 1.3

Выпадения цезия-137 из атмосферы, Бк/$м^2$ * год

Территория	1991 г.	1992 г.	1993 г.	1994 г.	1995 г.
Юго-запад ЕТР	48	8,6	9,7	14,4	10
Центр ЕТР	5,7	5,7	3,6	4,1	4
Юг ЕТР	12,2	3,1	2,5	3,1	3

2. Населенные пункты

Наибольший объем работ по мониторингу радиационной обстановки и загрязненных после аварии территорий, был связан с получением информации об уровнях загрязнения населенных пунктов. По состоянию на 1995 г. были обследованы 11457 пунктов в 23 областях России. В этих пунктах были отобраны около 90000 проб для последующего гамма-спектрометрического анализа. В обобщенном виде результаты этой работы представлены в табл.2.1-2.3.

Известно, что в соответствии с законом РСФСР от 15 мая 1991 г. "О социальной защите граждан, подвергшихся воздействию радиации вследствие катастрофы на ЧАЭС", уровни загрязнения населенных пунктов, начиная с которых должны осуществляться контрмеры по снижению доз облучения населения, составляют по цезию-137 - 1 Кюри/км2, по стронцию-90 - 3 Кюри/км2, по плутонию-239 - 0,1 Кюри/км2, а годовая доза внешнего и внутреннего облучения не должна превышать 1 мЗв (0,1 бэр). Как видно из таблиц 3.4-3.6, ни в одном пункте России нет превышений этих уровней загрязнения стронцием-90 и плутонием-239. Уровень загрязнения цезием 137 превышает 1 Кюри/км2 в 4581 пункте.

По данным о загрязнении территории населенных пунктов и данных о загрязнении продуктов питания в этих пунктах были проведены расчеты годовых доз облучения населения.
Расчеты показали, что превышения уровня облучения в 1 мЗв/год могут быть в 527 пунктах, причем вклад в дозу цезия-137 составляет более 90 %, а вклад плутония-239 ниже 1%.

Таблица 2.I

РАСПРЕДЕЛЕНИЕ
КОЛИЧЕСТВА НАСЕЛЕННЫХ ПУНКТОВ РОССИЙСКОЙ ФЕДЕРАЦИИ
ПО УРОВНЯМ ЗАГРЯЗНЕНИЯ СТРОНЦИЕМ-90
(по состоянию на январь 1996 г.)

No	Область	Всего нас. пун.	<0.1 Ku/км²	0.1 - 0.5 Ku/км²	0.5 - 1 Ku/км²	1 - 2 Ku/км²
1	Брянская	491	164	284	37	6
2	Калужская	92	33	58	1	
3	Ленинградская	13	13			
4	Орловская	21	2	19		
5	Рязанская	17	10	7		
6	Тульская	58	6	52		
	Всего	692	228	420	38	6

Таблица 2.2

РАСПРЕДЕЛЕНИЕ
КОЛИЧЕСТВА НАСЕЛЕННЫХ ПУНКТОВ РОССИЙСКОЙ ФЕДЕРАЦИИ
ПО УРОВНЯМ ЗАГРЯЗНЕНИЯ ПЛУТОНИЕМ-239+240
(по состоянию на январь 1996 г.)

No	Область	Всего нас. пун.	<0.001 Ku/км²	0.001 - 0.005 Ku/км²	0.005 - 0.01 Ku/км²	0.01 - 0.02 Ku/км²
1	Брянская	86	7	70	5	4
2	Калужская	3		2	1	
3	Рязанская	5	2	3		
4	Тульская	4		3	1	
	Всего	98	9	78	7	4

Таблица 2.3

РАСПРЕДЕЛЕНИЕ
КОЛИЧЕСТВА НАСЕЛЕННЫХ ПУНКТОВ РОССИЙСКОЙ ФЕДЕРАЦИИ
ПО УРОВНЯМ ЗАГРЯЗНЕНИЯ ЦЕЗИЕМ-137
(по состоянию на январь 1996 г.)

No	Область	Всего н/п	Всего проб	<1 Ku/км^2 н/п	<1 Ku/км^2 проб	1 - 5 Ku/км^2 н/п	1 - 5 Ku/км^2 проб	5 - 15 Ku/км^2 н/п	5 - 15 Ku/км^2 проб	15 - 40 Ku/км^2 н/п	15 - 40 Ku/км^2 проб
1	Башкортостан	16	91	16	91						
2	Белгородская	550	3617	327	2276	223	1341				
3	Брянская	2022	20859	1166	7656	505	5477	260	5031	91	2695
4	Волгоградская	5	24	2	10	3	14				
5	Воронежская	1208	9673	967	7728	241	1945				
6	Калужская	610	5522	267	1559	277	3075	66	888		
7	Курская	1116	6528	925	5104	191	1424				
8	Ленинградская	160	1745	75	849	85	896				
9	Липецкая	215	1628	128	953	87	675				
10	Марий Эл	25	74	25	74						
11	Мордовия	395	1502	351	1261	44	241				
12	Московская	9	51	9	51						
13	Нижегородская	141	762	141	762						
14	Новгородская	85	497	85	497						
15	Орловская	1575	10183	709	4346	852	5680	14	157		
16	Пензенская	120	838	96	714	24	124				
17	Ростовская	2	10	2	10						
18	Рязанская	556	7076	264	3457	292	3619				
19	Смоленская	89	517	89	517						
20	Тамбовская	123	980	117	919	6	61				
21	Тульская	2370	18371	1099	5818	1151	10763	120	1790		
22	Ульяновская	133	592	125	553	8	39				
23	Чувашия	33	93	33	93						
	Всего	11558	91233	7018	45298	3989	35374	460	7866	91	2695

3. Водные объекты

В течение 1991-95 г.г. наблюдения за уровнем радиоактивного загрязнения речных вод на территории России в зоне влияния аварии на ЧАЭС проводились на следующих стационарных пунктах контроля:

а). р.Ипуть (створы Крутояр, Ущерпье, Вышков).

б). р.Ока (г.Белев).

в). р.Плава (г.Плавск).

г). р.Упа (г.Тула).

д). р.Жиздра (г.Козельск).

Наблюдения на всех этих реках практически были начаты с конца 1986 г. Кроме того, НПО "Тайфун" производил наблюдения на р.Ипуть, водосбор которой являлся экспериментальным полигоном для апробации и отработки методов и средств контроля.

В таблице 3.1 и приведены полученные в 1991-95 г.г. данные по содержанию радионуклидов в воде указанных выше рек. Кроме того, в 1992 г. было проведено обследование радиоактивного загрязнения вод протекающей по Калужскому "цезиевому пятну" р.Рессета и ее притоков (пункты контроля на р.Рессета - д.Теребень, д.Рессета; на р.Ловатянка - д.Берестна, д.Ловатянка; на р.Дубна - д.М.Дворики). Содержание цезия-137 в воде составило - 15-44 мБк/л, стронция-90 - 85-220 мБк/л.

Из приведенных данных видно, что наблюдаемые уровни загрязнения речной воды цезием-137 существенно ниже как допустимой концентрации для питьевой воды ДК = 555 Бк/л 1,5Е-8 Ки/л), так и норматива ВДУ-91 для цезия-137 18,5 Бк/л (500 пКи/л). То же относится и к содержанию стронция-90 в речной воде. Так, наблюдавшиеся в 1992-93 г.г. уровни загрязнения стронцием-90 воды р.Ипуть имеют порядок величины 40 мБк/л (1 пКи/л), что существенно ниже норматива ВДУ-91 для стронция-90 3,7 Бк/л (100 пКи/л) (табл.3.2).

Вместе с тем, в ходе работ по контролю радиоактивного загрязнения водных объектов, находящихся на территории России, загрязненной после аварии на ЧАЭС, было установлено, что в некоторых малых водоемах и водотоках (ручьи, озера) наблюдаются уровни загрязнения воды, приближающиеся к предельно допустимым по нормативу ВДУ-91 для цезия-137 и стронция-90.

Поэтому оказалась важной задача комплексного мониторинга загрязнения долгоживущими радионуклидами (цезий-137 и стронций-90) малых водоемов и водотоков. Такие работы были начаты с 1992 г. на двух озерах Брянской области, находящихся в зоне с плотностью загрязнения цезием-137, превышающей 40 Ки/км2: - оз.Кожановское (слабопроточное озеро на водосборе р.Ипуть) и оз.Святое (бессточное озеро на водосборе р.Беседь).

Данные о концентрации цезия-137 и стронция-90 в воде данных озер в 1993-1995 г.г. представлены в таблице 3.3, из которой видно, что в отдельных случаях имело место превышение норматива ВДУ-91 по цезию-137 в воде. Высоким оказалось и содержание цезия-137 в рыбе из оз.Кожановское, в 1992 г. оно было в среднем на порядок выше норматива ВДУ-88 по рыбе (до 40 кБк/кг сырого веса).

Задача мониторинга радиоактивного загрязнения слабопроточных малых водоемов и малых водотоков в зоне влияния аварии на ЧАЭС остается по-прежнему актуальной, и в последующие годы целесообразно провести работы по картированию уровней загрязнения на малых водных объектах наиболее загрязненных районов.

Таблица 3.1

Цезий-137 в воде рек Упа, Плава, Ока и Жиздра, мБк/л

Река	1991 г.	1992 г.	1993 г.	1994 г.	1995 г.
Ипуть (Тула)	150	< 20-38	< 20-80	< 20	< 20
Плава (Плавск)	180	22-52	< 20-100	< 20	< 20
Ока (Белев)	67	< 15-34	< 20-170	< 20-26	< 20
Жиздра (Козельск)	63	< 20	< 20-52	< 20-90	22

Таблица 3.2

Концентрация цезия-137 и стронция-90 в воде р.Ипуть, мБк/л

Створ реки	Цезий-137		Стронций-90	
	1992 г.	1993 г.	1992 г.	1993 г.
Крутояр	2,6-41	22	15-22	-
Ущерпье	41-210	60-80	30-44	-
Вышков	100-350	667-470	22-56	30

Таблица 3.3

Концентрация цезия-137 и стронция-90 в воде озер Кожановское и Святое, Бк/л

Измерения	Цезий-137	Стронций-90
	Озеро Кожановское (1992-93 г.г.)	
Диапазон	9,3 - 16,7	1,4 - 1,7
Среднее	12,6	1,6
	Озеро Святое (1993 г.)	
Диапазон	20,7 - 50,7	0,2 - 0,6
Среднее	35,7	0,41

В Ы В О Д Ы

Исходя из полученных в 1991-1995 годах результатах мониторинга за состоянием радиоактивного загрязнения природных сред, вследствие аварии на ЧАЭС на территории России следует, на период 1996-2000 годы направить усилия на выполнение следующих задач:

1.Уточнить радиационную обстановку и прогноз ее изменения в населенных пунктах, где уровни облучения населения превышают 1 мзв/год, а также в населенных пунктах находящихся в зоне отчуждения [из которых население было переселено в 1986 -1990 годах] в которых годовая доза облучения меньше 5 мзв/год.

2. Провести углубленные исследования механизма формирования радиоактивного загрязнения слабопроточных малых водоемов широко используемых населением для водоснабжения и вопросов реабилитации этих водоемов.

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RESULTS AND FUTURE TRENDS OF RESEARCH ON THE CHERNOBYL ACCIDENT CLEAN-UP PROGRAMME IN THE RUSSIAN FEDERATION

XA9745870

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ИТОГИ И ПЕРСПЕКТИВЫ НАУЧНЫХ ИССЛЕДОВАНИЙ ПО ПРОГРАММЕ ЛИКВИДАЦИИ ПОСЛЕДСТВИЙ ЧЕРНОБЫЛЬСКОЙ АВАРИИ В РФ

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А.А.ТЕР-СААКОВ
Министерство по чрезвычайным ситуациям РФ,
Всероссийский институт гражданской обороны
и чрезвычайных ситуаций.
Москва.Российская Федерация

The results of research relating to liquidation of consequences of ChNPP accident taking into account medical, social, agricultural, economic, radioecological, etc. aspects have been discussed. The problem of evaluating and making more precise the scales and degree of radiocontamination of the RF territory as well as estimating the current and accumulated doses of public exposure on the whole, has been solved, with the exception of dose reconstruction in the period of acute exposure. Modified farming methods provide for ecologically pure products which comply with valid sanitary regulations and requirements, these products being yielded from the area with contamination levels exceeding 40 Ci/sq.km. The registered levels, structure and dynamics of cancer disease incidence and mortality at radiocontaminated areas tend steadily to grow. However, it is worth mentioning that the latter fact characterizes the situation for the whole counntry in general and does not correlate with the radiation-induced exposure. Increase in the number of thyroid pathology cases including thyroid cancer for children and teenagers in some districts of Bryansk region exceeds the anticipated rate and can be associated with the exposure resulted from the accident. Mitigation of socio-psychological impact of the radiation accident still remains one of the most important problems. Radiation factor appreciably dominates among other risk factors for the population. Revival of economics in he affected regions fails to keep pace with the corresponding requirements. Considerable progress has been achieved in

drawing general conclusions from the experience accumulated in the post-accident period as well as in elaboration of theory of countermeasures.

Авария на Чернобыльской АЭС в апреле 1986 г. по своей масштабности, несомненно, относится к разряду глобальных, поскольку радиоактивное загрязнение продуктами аварийных выбросов коснулось не только трех государств СНГ - Украины, Беларуси и России, но и большинства Европейских стран, а радиоактивные следы обнаруживались практически по всему Северному полушарию. Но масштабность аварии определялась не только размерами загрязненной территории и количеством выброшенных в окружающую среду радионуклидов, но и количеством возникших новых исключительно сложных проблем, затрагивающих в той или иной степени практически все стороны жизни общества - экономические, медицинские, социальные, психологические, нравственные. Авария такого характера и масштаба представлялась столь маловероятной, что многие службы оказались не готовыми к оперативной и эффективной ее локализации и ликвидации последствий. Да и мировая наука и практика не обладали готовыми решениями, поэтому многие задачи и проблемы пришлось решать с нуля, что предопределило масштабность и направленность научных исследований по изучению развития поставарийной ситуации и ликвидации последствий аварии на всех стадиях.

Научные исследования, направленные, в первую очередь, на обеспече/ние эффективности практических мероприятий по защите населения и реабилитации пострадавших территорий РФ, велись до 1992 г. в рамках Союзно-республиканской программы по ликвидации последствий аварии на ЧАЭС, а затем "Единой государственной программы защиты населения РФ от воздействия последствий Чернобыльской катастрофы на 1992-95 гг. и на период до 2000 г." и Федеральной программы "Дети Чернобыля".

Чернобыльская программа предусматривает научные исследования на обширных территориях с различной степенью одномоментного радиоактивного загрязнения, приведшего к изъятию части земель из народно-хозяйственного пользования, отселению жителей ряда населенных пунктов и к хроническому облучению в малых дозах населения остальной части загрязненной территории. Направленность научных исследований определяется масштабами загрязненной территории, разнообразием природно-климатических условий, сочетанием в ряде случаев действия радиационных и нерадиационных факторов, изначально деформированной психо-социальной обстановкой и практическим отсутствием нормативно-правовой основы и рекомендаций по медико-социальной защите населения и реабилитации пострадавших территорий на восстановительной стадии аварии.

Программа "Дети Чернобыля" посвящена изучению медицинских последствий облучения детей, в том числе и внутриутробно, патологии беременности и репродуктивной функции и разработке методов медицинской и социально-психологической помощи этим группам населения. Уровни облучения определялись ударными нагрузками на ЩЖ в первые дни и недели после аварии и хроническим воздействием в последующие годы.

К настоящему времени последствия аварии на ЧАЭС на территории России достаточно хорошо и всесторонне изучены: составлены карты плотности загрязнения долгоживущими радионуклидами, изданы "Справочники по радиационной обстановке и дозам облучения

Таблица

Площади областей России с плотностью загрязнения цезием-137 1-5Ки/кв км, 5-15 Ки/кв км, 15-40 и выше 40 Ки/кв км, отношение загрязненных площадей к общей площади территорий в %

N п/п	Область	ПЛОЩАДЬ (кв км) общая	1 - 5	%	5 -15	%	15-40	%	выше 40	%
1	Белгородская	27100	1620	6.0	-	-	-	-	-	
2	Брянская	34900	6750	19,3	2629	7.5	2130	6,1	212	0,9
3	Воронежская	52400	1320	2.5	-	-	-	-	-	-
4	Калужская	29900	3500	11.7	1419	4,7	-	-	-	-
5	Курская	29800	1220	4,1	-	-	-	-	-	-
6	Липецкая	24100	1690	7,0	-	-	-	-	-	-
7	Ленинградская	85900	850	1,0	-	-	-	-	-	-
8	Мордовия	26200	1630	6,3	-	-	-	-	-	-
9	Нижегородская	74900	15	0,02	-	-	-	-	-	-
10	Орловская	24700	6640	26,4	132	0.5	-	-	-	-
11	Пензенская	43200	4120	9.6	-	-	-	-	-	-
12	Рязанская	39600	5210	13,0	-	-	-	-	-	-
13	Саратовская	100200	150	0,2	-	-	-	-	-	-
14	Смоленская	49800	100	0,2	-	-	-	-	-	-
15	Тамбовская	34300	510	1,0	-	-	-	-	-	-
16	Тульская	25700	10220	29,7	1271	4,9	-	-	-	-
17	Ульяновская	37300	1060	2,9	-	-	-	-	-	-
18	Татарстан	68100	110	0,16	-	-	-	-	-	-
19	Чувашия	18000	80	0.044	-	-	-	-	-	-

населения районов Российской Федерации,подвергшихся радиоактивному загрязнению вследствии аварии на ЧАЭС",создан Российский Государственный медико-дозиметрический регистр (РГМДР),на базе которого проводится изучение состояния здоровья населения и ликвидаторов и т.д. Различные аспекты последствий Чернобыльской катастрофы обсуждались на многочисленных конференциях и симпозиумах как внутрироссийских,так и международных.

Наибольшее внимание при исследовании радиоактивного загрязнения на территории России обращалось на загрязнение цезием-137, поскольку ни в одном из населенных пунктов критерии по загрязнению Sr-90 или Pu-239,240 не превышаются.

Масштабы радиоактивного загрязнения территорий по данным Росгидромета приведены в таблице. Как видно из таблицы,уровни загрязнения территории,превышающие 555 кБк/кв м (15 Ки/кв км) по Cs-137,наблюдаются лишь в Брянской обл.

Уровень загрязнения атмосферного воздуха и поверхностных вод по данным,полученным на сети Росгидромета, на несколько порядков ниже ДКб,принятых для условий нормальной эксплуатации атомных предприятий [1].

Загрязнение атмосферного воздуха определяется в основном ветровым подъемом, и соответственно - максимальные концентрации долгоживущих радионуклидов отмечаются в воздухе Злынковского и Новозыбковского районов Брянской обл.[2].

Концентрации радионуклидов во всех обследованных водоемах и водотоках существенно ниже допустимых величин для питьевой воды (ДКб) как по Sr-90,так и по Cs-137. В частности,в р.Ипуть,протекающей по наиболее загрязненным райнам Брянской обл.,максимальная концентрация Cs-137 достигает 0,4 Бк/л,а Sr-90 - 0,06 Бк/л.Самые высокие концентрации радионуклидов отмечаются в оз.Кожановское и оз.Святое Брянской обл.В первом концентрация Cs-137 составляет 12 Бк/л,Sr-90 - 1,5 Бк/л,а во втором - 20 и 0,56 Бк/л,соответственно. [2].

Анализ результатов исследований радиационной обстановки, выполненных за прошедшее после аварии время, позволяет заключить, что задача оценки и уточнения масштабов и степени радиоактивного загрязнения на территории России в основном решена. В то же время "белым пятном" до настоящего времени остается период формирования радиоактивных выпадений, когда основной вклад в радиационную нагрузку на население загрязненных радионуклидами территорий определялся не цезием, а I-131 и другими короткоживущими радионуклидами, влияние которых на радиационную обстановку к моменту начала широкомасштабных исследований стало незначительным. Отсутствие надежных данных о параметрах радиационной обстановки и ее динамике в первые дни и недели после аварии не позволяет оценить с достаточной степенью точности дозовые нагрузки на население на начальном периоде послеаварийной ситуации и, вследствие этого, проблема реконструкции радиационной обстановки на территории РФ на указанный период продолжает оставаться актуальной и требующей продолжения исследований.

С точки зрения организации агропромышленного производства при авариях типа "чернобыльской" ведущими отечественными исследователями предложено выделить четыре периода по ликвидации последствий аварии : ранний - 10-12 дней после аварии; второй - 2-3 месяца после аварии, третий - по истечении полутора лет и четвертый по истечению 1,5 - 2 лет; для каждого из этих периодов разработаны проекты программы действий и рекомендации по ведению агропромышленного производства для получения чистой продукции [3].

Полученные данные свидетельствуют о том, что под влиянием естественных природных процессов и в результате широкого применения контрмер наиболее быстрое улучшение радиационной обстановки в сельскохозяйственной сфере происходило в первые 2-3 года после аварии на ЧАЭС. Это выразилось в многократном снижении интенсивности перехода радионуклидов из почвы в растения, что привело в среднем к 3-5 кратному снижению уровней загрязнения продукции растениеводства и животноводства. В последующие годы эти изменения носили хотя и четко выраженный, но более медленный характер. По истечению 9 лет после аварии основной акцент по снижению перехода радионуклидов в растениях на пахотных землях, а также на лугах и пастбищах сделан на химизацию земледелия. Результаты исследований, включая данные 1993-1994гг., показали, что какие-либо мероприятия по снижению содержания цезия-137 в сельскохозяйственной продукции целесообразно лишь при плотностях загрязнения почвы, превышающие 555 кБк/кв м (15 Ки/кв км). В связи с этим было большое внимание уделено исследованиям на сельскохозяйственных угодьях с плотностью загрязнения выше 1500 кБк/кв м (40 Ки/кв км). Для этих территорий разработаны методы , которые позволяют не только использовать эти земли, но и снять фитопатологическую опасность (в связи с неконтролируемой заготовкой на ней кормов). На основе полученного опыта разработаны проекты руководств, в том числе "Рекомендации по применению системы контрмер в сельскохозяйственном производстве","Руководство по применению системы севооборотов и усовершенствованные технологии возделывания сельхозкультур на загрязненных территориях","Усовершенствованные технологии реабилитации пойменых и заболоченных угодий на разных уровнях радиоактивного загрязнения" и др. Эти документы должны быть доведены до уровня нормативных,и, в первую очередь, следует завершить разработку серии документов, регламентирующих ведение сельскохозяйственного производства в послеаварийный период [3].

Анализ и обобщение результатов научно-практических работ по ликвидации последствий радиоактивного загрязнения лесных экосистем показывает, что в качестве первоочередной задачи на восстановительной фазе Чернобыльской аварии необходимо признать разработку новых подходов к ведению лесного хозяйства на территориях с разными уровнями радиоактивного загрязнения, предусматривающую переход от ограничительных методов к активным мероприятиям в зонах, где разрешено проживание населения. В 1988г. были введены в действие "Временные рекомендации по ведению лесного хозяйства в условиях радиоактивного загрязнения".В соответствии с этим документом вся загрязненная территория делится на три зоны. Первая с плотностью загрязнения от 37 до 555 кБк/кв м (1 - 15 Ки/кв км), вторая от 555 до 1500 кБк/кв м (15 - 40 Ки/кв км) и третья 1500 кБк/кв м (40 Ки/кв км) и более. В первой зоне древесину и продукты ее переработки рекомендовано использовать без ограничений,допускается использование пищевых продуктов леса и лекарственного сырья с обязательной проверкой на содержание радионуклидов. Во второй зоне заготовка древесины разрешена в зимнее время при наличии снежного покрова, использование древесины в качестве топлива и заготовка пищевых продуктов леса запрещается. В третьей зоне лесохозяйственная деятельность запрещена. В зонах отселения и отчуждения по-прежнему актуальной остается задача по регламентированию работ, связанных с профилактикой фитоопасности и предупреждению пожаров [4].

Проведенные исследования в последующие годы позволили получить большой статистически достоверный материал свидетельствующий о том,что удельная радиоактивность древесных растений является не только функцией плотности загрязнения цезием-137, но сильно зависит от химического состава почвы,ее влажности, микрорельефа, сезона года и его агроклиматических условий, древесной породы,класса физиологического состояния дерева, а также местоположения взятой пробы по высоте ствола или кроны. Установлено также, что удельная активность древесины, коры, хвои, листьев в одном и том же типе леса, на одних и тех же участках в разные годы меняется до двадцати и более раз. По данным ВНИИХлесхоза, полученным в 1992-1995 годах, эффективная доза облучения работников лесного хозяйства при 8 часовом рабочем дне на территориях с плотностью загрязнения Cs-137 до 1500 кБк/кв м (40 Ки/кв.км) не превышает установленного предела дозы, в зонах с плотностью загрязнения свыше 1500 кБк/кв м (40 Ки/кв км) общее время пребывания работников в этой зоне не должно быть более 100 часов в году [4].

На востановительной фазе аварии исследования должны быть направлены на интенсификацию лесохозяйственной деятельности и повышение эффективности лесопользования на территориях, подвергшихся радиоактивному загрязнению, и на завершение работ по созданию нормативных документов, регламентирующих лесохозяйственную деятельность на загрязненных территориях.

Население, проживающее на территориях, подвергшихся радиоактивному загрязнению,оказалось под воздействием физических, химических и социальных факторов. Попытка анализа и вычленения патогенных аварийных эффектов столкнулась с необходимостью дополнительного учета генетических и эндемических факторов,включая йодную эндемию, краевую патологию. К числу объективных факторов, способных повлиять на оценку значимости радиационного фактора, относится также и улучшение медицинского обслуживания и , как следствие, лучшая диагностика, а порой и гипердиагностика, в том числе и опухолевых заболеваний.

Материалы исследований, полученные в пяти областях РФ - Брянской, Калужской, Орловской, Тульской и Рязанской областей свидетельствуют о том, что структура злокачественных заболеваний среди населения не претерпела в послеаварийный период существенного изменения, хотя показатели заболеваемости имеют устойчивую тенденцию к росту. Однако однозначная зависимость от уровней облучения не установлена. Характерно, что наивысшие уровни онкозаболеваемости среди обследованных областей, наблюдаются в Брянской и Рязанской областях, хотя Брянская область наиболее загрязнена, а Рязанская - наименее. Поэтому формирование наблюдаемых уровней онкозаболеваемости и смертности, структура и динамика обусловлены комплексом факторов, сложившихся до аварии [5,6] и отражают сложную тенденцию, характерную для всей России в целом. Исключение составляют раки щитовидной железы, рост которых в Брянской области опережает ожидаемые уровни и может быть связан с радиационным воздействием. Однако, и в этом случае для получения достоверного подтверждения причинно-следственной связи необходимо проведение дальнейших аналитических и динамических наблюдений, в том числе необходима корректная реконструкция доз облучения щитовидной железы [5,7].

Что касается участников ликвидации последствий Чернобыльской катастрофы, то на основе материалов, накопленных в Российском государственном медико-дозиметрическом регистре

(РГМДР) за период 1986-1994гг. (примерно 160 тыс.чел.) специалисты пришли к выводу, что наблюдается зависимость между дозой внешнего облучения и онкологической заболеваемостью в целом, а также злокачественными новообразованиями органов пищеварения и брюшины [8]. Коэффициенты относительного риска онкозаболеваний и смертности, полученные по данным РГМДР,значительно превышают существующие оценки, что, по-видимому, связано с недооценкой доз, полученных ликвидаторами [9].

Научные исследования в рамках программы "Дети Чернобыля" выявили общие неблагоприятные тенденции в состоянии здоровья детского населения. В 11 областях, подвергшихся воздействию от Чернобыльской катастрофы, отмечен рост общей заболеваемости, младенческой смертности, снижение рождаемости. Прямая связь с радиационным воздействием не установлена за исключением патологии щитовидной железы - приобретенных гипотериозов и тиреотоксикозов, а также рака щитовидной железы. Группой риска развития тиреодной патологии в загрязненных районах являются дети, облученные внутриутробно или имевшие в момент аварии возраст 1-3 года. У этой кагорты спустя 7-8 лет после аварии отмечено увеличение частоты зоба 1-2-ой степени, что нехарактерно для детей из "чистых" районов [10].

Принимая во внимание то обстоятельство, что обеспокоенность жителей загрязненных районов и ликвидаторов состоянием своего здоровья является одним из дестабилизирующих факторов, дальнейшие медицинские исследования должны быть направлены прежде всего на долговременное изучение состояния здоровья этих контингентов лиц по широкому спектру заболеваний как гипотетически радиационно-индуцированных, так и не имеющих такой связи. Эти исследования требуют максимально корректных оценок интегральных эффективных доз облучения, особенно на ранней стадии аварии, и облучения щитовидной железы, прежде всего детского контингента.

Проблема смягчения социально-психологических последствий чернобыльской аварии является одной из важнейших задач охраны здоровья и реабилитации населения. По данным многих исследователей [11,12,13] опасение за свое здоровье в результате воздействия радиации выражено доминирует среди факторов риска у населения, проживающего на загрязненных территориях. Озабоченность жителей состоянием своего здоровья является источником психологического стресса, что не только само по себе является патогенным фактором, но и формирует повышенную чувствительность к новым стрессовым воздействиям. Но при этом все эти последствия субъективно ассоциируются с первопричиной возникшей ситуации - аварией на ЧАЭС и последующим радиационным воздействием. При этом следует учитывать и то обстоятельство, что поставарийная ситуация разворачивается на фоне общегосударственных социально-экономических потрясений, усугубляющих социальную напряженность и отягощающих психологический дисстресс. Таким образом образовалась,по сути, замкнутая самовозбуждающаяся система, входным импульсом явилось радиационное воздействие, возможные последствия которого многократно усилились и продолжают усиливаться в сознании людей благодаря просчетам в системе поставарийных мероприятий, тенденциозности в оценках возможных биологических эффектов,некорректным освещением событий средствами массовой информации,резким ростом цен и безработицы, снижением уровня жизни,политизацией ситуации. Не случайно еще в 1991 году в докладе Международного консультативного комитета [14] отмечалось, что "... принятые или запланированные в долгосрочном плане защитные меры, хотя и основывались на благих намерениях, в целом выходят за пределы того, что было строго необходимо с точки зрения обеспечения радиационной защиты".

По мнению социо-психологов, даже такие мероприятия, как обязательная сплошная диспансеризация зачастую оказывается скорее стрессирующим фактором, чем полезным [13]. Поставарийное законодательство закрепило определенный статус - статус жертвы - среди населения на загрязненных территориях, что также способствует формированию психологического дисстресса. Нельзя не учитывать и отрицательную роль средств массовой информации, которые в погоне за сенсационностью, а порой и из коньюктурных соображений создали негативный информационный фон, существенно подорвали доверие к решениям и предложениям ученых и специалистов. Действительно, целенаправленная дискредитация научно-обоснованных решений в СМИ и,как результат этого, постоянное общественное давление на ученых и специалистов привело к необоснованному со всех точек зрения - медицинской, экономической, социальной,наконец, психологической - ужесточению ограничительных мероприятий, к неоправданным экономическим затратам, к неадекватной психо-социальной реакции.

Под влиянием всех этих факторов сформировался психологический дисстресс, выражающийся в увеличении числа невротических расстройств, психосоматических симптомов, снижении уровня и интенсивности социального функционирования и т п. Поэтому, одной из основных составляющих, необходимых для решительного перелома социально-психологической обстановки на затронутых аварией территорий является переориентация населения в сторону всемерной личностной активизации, чему должны способствовать, в первую очередь, исследования, направленные на выявление истинной причины дестабилизирующих факторов, и создание объективного целевого информационного воздействия на население.

На фоне общего социально-экономического кризиса в стране экономика загрязненных после аварии на ЧАЭС территорий оказалась в особо сложном положении: спад производства, отток наиболее квалифицированной части населения - интеллигенции и работников промышленности и сельского хозяйства, разрушение потребительского сектора и т п. Поэтому научные исследования в этой части "Единой государственной программы.." были направлены не только на изучение причин деформации хозяйственно-экономической структуры пострадавших регионов, но и,прежде всего,на разработку эффективных механизмов их опережающего развития.

Создание условий для такого развития, по сути, является тем основанием,на котором можно строить комплексную реабилитацию регионов, включающую вопросы как чисто экономические, так и вопросы здравоохранения, демографические,социальные, психологические.

В широком смысле конечной целью экономической реабилитации является обеспечение более высокого уровня жизни,чем на не затронутых аварией территориях, как компенсацию за ущерб. Для этого необходима разработка и реализация программ встраивания в экономику загрязненных зон рыночных структур, принципов самофинансирования и саморазвития, самого широкого развития малого и среднего бизнеса как средства самоутверждения и реабилитации личности [15,16]. Это тем более важно, что по данным проведенных в Калужской области исследований [17] более половины охваченного социологическим опросом населения придерживается установки на собственную пассивность и социально-экономическое иждевенчество, ориентируясь лишь на государственную помощь. К сожалению, в настоящее время экономическое возрождение пострадавших территорий все еще отстает от требований времени, что, с одной стороны, обусловлено общегосударственными трудностями, но с другой стороны, и недостаточной эффективностью и оперативностью внедрения предлагаемых программ. Лишь в Калужской области осуществляется экспериментальная программа [18], имеющая целью демонстрацию преимущества новых принципов экономического развития регионов.

Большое внимание в научных исследованиях на загрязненных территориях уделялось вопросам поведения радионуклидов в окружающей среде, миграции по пищевым цепям, накоплению в организме и формированию доз облучения населения. Исследования проводились как в естественных условиях,так и на специально подготовленных полигонах в Новозыбковском районе Брянской области,отражающих все многообразие ландшафтно-геохимических особенностей загрязненных территорий [19].Основная задача, которая решалась этими исследованиями, заключалась в оценке текущих и ожидаемых эффективных доз, а также в реконструкции имевших место в первые дни после аварии эффективных и эквивалентных доз от короткоживущих радионуклидов, в первую очередь, от иода -131. Большое разнообразие естественных ландшафтно-геохимических условий, определяющих поведение и миграцию радионуклидов, потребовали углубленного исследования динамики радиационной обстановки для верификации параметров модели прогноза доз применительно к конкретным регионам. К настоящему времени выполнены оценки текущих годовых, накопленных по 1995 год и ожидаемых до 2056 года доз облучения практически для всех регионов РФ, подвергшихся радиоактивному загрязнению. Примерно 40 тыс жителей Брянской области могут в 1996 году получить свыше 1 мЗв/год - величину, рекомендуемую МКРЗ как предел дозы для населения при нормальной работе атомных предприятий и принятую в РФ как уровень невмешательства. В остальных регионах радиационно-гигиеническая обстановка такова, что превышение 1 мЗ/год не ожидается.

Что касается накопленной дозы, то в соответствии с "Концепцией радиационной, медицинской, социальной защиты и реабилитации населения Российской Федерации, подвергшегося аварийному облучению", принятой РНКРЗ, лица, получившие интегральную дозу более 70 мЗв классифицируются как облученные и заносятся в Национальный радиационно-эпидемиологический регистр. По оценкам к 1996 году численность этой категории лиц может составить 30-40 тыс человек, проживающих в Брянской области. В остальных регионах,по-видимому, не будет превышения 70 мЗв/год. К 2016 , т е за 70 лет после аварии общее число лиц категории "облученных" может возрасти еще на 10-20 тыс. Вопросы формирования доз облучения щитовидной железы радиоизотопами йода, а также от короткоживущих радионуклидов на ранней стадии аварии остаются все еще до конца не решенными.

Корректная оценка облучения щитовидной железы имеет особое значение, поскольку это единственный орган, наблюдаемая патология которого у детей и подростков по предварительным данным связана с радиационным воздействием [20].

Расчет коллективных доз облучения населения,обусловленных чернобыльскими выпадениями,выполненный на основе данных,полученных в процессе выполнения программы "Атлас",показал,что по сравнению с уровнем естественного облучения вклад чернобыльской компоненты ощутим лишь в западных районах Брянской области.В остальных регионах этот вклад практически пренебрежим.

Что касается сравнения с цезиевым доаварийным фоном (глобальные выпадения), то в этом случае заметный прирост коллективной дозы наблюдается в Брянской (5,2 раза), Тульской (3,7 раза) и Орловской областях (2,5 раза).

В процессе ликвидации последствий аварии на ЧАЭС основная направленность работ заключалась, прежде всего, в снижении дозовых нагрузок на население и ликвидаторов, причем осуществлялись такие мероприятия практически без учета экономического фактора. На ранней стадии аварии такой подход был вполне оправдан, поскольку речь шла о предотвращении, в первую очередь, острых поражений. Однако в дальнейшем, когда в результате принятых мер и естественных процессов уровни облучения населения снизились до величин, способных вызвать в соответствии с концепцией безпороговости лишь отдаленные стохастические эффекты, основу любого рода защитных мероприятий должен составить оптимизированный подход, учитывающий все составляющие выгоды и издержек. Поэтому большое внимание в научных исследованиях уделялось созданию научно-обоснованной нормативной базы радиационной защиты населения и ликвидации последствий радиационных аварий такого крупного масштаба, разработке инструктивно-методических документов, относящихся ко всем аспектам поставарийной ситуации, созданию теоретических основ оптимизированной системы контрмер для случаев радиационных аварий, затрагивающих большие территории и значительные контингенты людей [21-27].

Завершение работ по теоретическим основам контрмер и рекомендациям по принятию управленческих решений на прмежуточной и восстановительных фазах поставарийной обстановки, обобщающих весь опыт не только Чернобыльской, но и других радиационных аварий, в первую очередь, Уральской, является одним из приоритетных направлений на ближайшее время. Это тем более важно, что в настоящее время в РФ предполагается в соответствии с принятой концепцией(22) переход на новые критерии зонирования территорий - от плотности загрязнения к эффективной дозе. Мера столь же прогрессивная с точки зрения социально-экономической обоснованности, сколь и запоздалая. Отсутствие опыта, недостаточно проработанный прогноз социально-экономических последствий и ,наконец, общественно-политическое давление обусловили принятие "Закона РФ о социальной защите граждан,подвергшихся воздействию радиации вследствии катастрофы на Чернобыльской АЭС" основанного на зонирование по плотности радиоактивного загрязнения территории. Практика показала неэффективность такого подхода,приведшего к неоправданно высоким экономическим затратам и неадекватным психо-социальным последствиям. Это обстоятельство является одним из серьезнейших уроков Чернобыля, и перестройка всей структуры социальной защиты и реабилитации населения представляет собой в настоящее время чрезвычайно сложную задачу.

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DYNAMICS OF BEHAVIOUR OF THE CHERNOBYL RADIONUCLIDES IN NATURAL ENVIRONMENTS

XA9745871

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If to refer air, water, soil and vegetation cover to major natural environments then a relative content of different radionuclides in these environments and the velocity they pass from one medium to another can determine the idea about the dynamics of their behaviour.

In the last 10 years the USSR Goskomgidromet and then Rosgidromet conducted both deepened particular works on the dynamics of the behaviour of the "Chernobyl" radionuclides in natural environments and large-scale generalized works in the same direction.

As a unique example of determining the dynamics of behaviour of caesium-137 radionuclides in the 60-km zone of the CNPP one can consider a grand experiment on quantitative measuring of the secondary contamination of the atmosphere by this very radionuclide in the process the dust is raised by the wind. For this purpose over an area of 11.5 thousand km^2 (60-km zone) a reference network was established. Using a radial scheme one exposed here at a height of 1 m more than 500 standard gauze trays. The trays were exposed for a month. At the same time soil samples were taken near reference points and analyzed.

The intercomparison of two sets of such data results in finding that the contamination field variability because of the dust transport makes a magnitude below 10^{-3} (per month).

МЕЖДУНАРОДНАЯ КОНФЕРЕНЦИЯ
ДЕСЯТИЛЕТИЕ ПОСЛЕ ЧЕРНОБЫЛЯ:
ОЦЕНКА ПОСЛЕДСТВИЙ АВАРИИ

ДИНАМИКА ПОВЕДЕНИЯ “ЧЕРНОБЫЛЬСКИХ” РАДИОНУКЛИДОВ В ПРИРОДНЫХ СРЕДАХ

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Если к основным природным средам отнести воздух, воду, почву и растительный покров, то именно по относительному содержанию в этих средах и скорости перехода из одной среды в другую различных радионуклидов и может быть составлено представление о динамике их поведения.

Очевидно, что подвижность радионуклида напрямую связана с подвижностью среды, т.е. один и тот же радионуклид более подвижен в воздухе относительно воды, и в воде относительно почвы.

Хорошо известно, что первичное загрязнение окружающей среды непосредственно после взрыва реактора IV-ого блока ЧАЭС состояло в загрязнении атмосферного воздуха громадным количеством выброшенной при взрыве радиоактивности. В процессе распространения в атмосфере выброшенной из реактора радиоактивности и осаждение ее на дневную поверхность происходило загрязнение почв, лесов и поверхностных вод. Так был сформирован первичный источник загрязнения всех природных сред, который затем стал меняться за счет различных процессов миграции.

При прочих равных обстоятельствах поведение конкретного радионуклида во времени и пространстве зависит от: (а) размера частиц аэрозоля, в котором размещен (инкорпорирован) данный радионуклид и (в) прочности связи этого радионуклида с той частицей, в которую он инкорпорирован. При этом фактор (а) практически полностью определяет понятие "летучести радионуклида", т.е. дальности распространения его при переносе в атмосфере, а фактор (в) определяет поведение радионуклида в воде и при горизонтальной и вертикальной миграции в почве.

Из таких общих предпосылок ясно, что тема, обозначенная в названии доклада, не может быть полностью раскрыта в докладе ограниченного объема. Поэтому ограничимся двумя примерами и общими выводами.

Приведем пример динамики изменения радионуклидного состава выбросов из аварийного реактора в процессе распространения на дальние расстояния. В мае-июне 1986 г. в ближней зоне ЧАЭС (30-60 км) было отобрано и проанализировано большое число проб, по которым впервые и был определен радионуклидный состав выпадений. Отбор проб проводился в основном вдоль автодорог, по которым можно было проехать на автомашинах, а в труднодоступных секторах работа выполнялась с помощью вертолетов. В частности, к такому относится почти весь северо-западный сектор. Анализ проб на полупроводниковых гамма-спектрометрах был выполнен в Институте ядерных исследований АН Украины и Институте прикладной геофизики (Москва). В итоге уже к концу мая мы имели общие представления о радионуклидном составе загрязнения ближней зоны. Это представление отражает табл.1, в которую помещены данные по всем тем пробам, при отборе которых мощность дозы гамма-излучения на высоте 1 м составляла от 2 до 10 мР/час (хотя были пробы и с большими, и с меньшими уовнями радиации). Из таблицы следует, что

Таблица 1

Относительный радионуклидный состав выпадений в мае-июне 1986 г. в ближней зоне Чернобыльской АЭС (A_i/A_{95} - отношение активности i-го радионуклида к активности циркония-95 на момент аварии, f^i_{95} - коэффициент фракционирования i-ого радионуклида относительно циркония-95).

Радио-нуклид	Период полурас-пада	Южный сектор A_i/A_{95}	Южный сектор f_{95}	Западный сектор A_i/A_{95}	Западный сектор f_{95}	Северный сектор A_i/A_{95}	Северный сектор f_{95}
Sr-89	51день	1,6	3,0	0,6	1,3	0,3	0,6
Sr-90	28,5 лет	0,16	2,0	0,03	0,4	0,03	0,4
Y -91	58,5 дня	-	-	0,6	0,9	0,5	0,8
Zr-95	65 "-"	1,0	1,0	1,0	1,0	1,0	1,0
Mo-99	2,73 "-"	-	-	1,4	1,6	-	-
Ru-103	39 "-"	0,7	0,7	0,7	0,7	1,6	1,5
Ru-106	368 "-"	0,2	0,35	0,3	0,5	0,4	0,7
I-131	8,01"-"	0,6	1,0	0,6	0,6	6,0	10
Te-132	3,27 "-"	0,9	1,2	3,8	5,3	10	14
Cs-134	2,06 лет	0,015	0,1	0,14	0,9	0,18	1,2
Cs-137	30,1 год	0,04	0,4	0,2	1,8	0,3	2,7
Ba-140	12,6 дн.	0,9	1,0	1,6	1,5	1,1	1,0
Ce-141	32,5 дн.	1,1	1,2	1,1	1,2	1,1	1,2
Ce-144	284 дня	0,6	0,6	0,7	0,7	0,6	0,6
Np-239	2,35 дня	-	-	9,0	-	-	-

радионуклидный состав выпадений в ближней зоне ЧАЭС представлен полным набором осколочных радионуклидов (дополнительно к ним Cs-134 и Np-239 - наведенные) в соотношениях, не очень отличающихся от тех, в которых они были наработаны в реакторе к моменту аварии. Исключение из этого правила составляют лишь I-131 и Te-132 в северном секторе.

Таблица 2

Концентрации радионуклидов в атмосфере над акваторией Атлантического океана по наблюдениям на научно-исследовательском судне "Э.Кренкель", приведенные на дату отбора пробы (числитель - концентрации $x10^{-15}$ Ки/м^3; знаменатель - концентрации относительно концентрации цезия-137)

Радио-нуклиды	Дата/широта/долгота				
	5.05.86 50°00 с.ш. 31°10 з.д.	6.05.86 50°60 с.ш. 26°00 з.д.	7.05.86 50°00 с.ш. 21°04 з.д.	8.05.86 50°00 с.ш. 16°00 з.д.	9.05.86 49°44 с.ш. 08°50 з.д.
Стронций-89	0.7 / 0.028	1.4 / 0.093	1.1 / 0.09	н	н
Стронций-90	0.2 / 0.008	0.9 / 0.06	0.5 / 0.08	1.2 / 0.07	0.3 / 0.006
Иттрий-91	0.4 / 0.016	0.5 / 0.03	0.4 / 0.03	н	н
Рутений-103	7.2 / 0.29	10.1 / 0.68	12.1 / 1.0	10.6 / 0.63	9.1 / 0.17
Иод-131	158 / 6.4	138 / 9.3	95 / 7.8	28 / 1.7	6.9 / 0.13
Теллур-132	12.7 / 0.51	20.5 / 1.38	3.0 / 0.25	8.7 / 0.52	н
Барий-140	2.6 / 0.11	3.6 / 0.24	н	н	н
Цезий-134	10.3 / 0.42	6.2 / 0.42	5.1 / 0.42	7.0 / 0.42	22.7 / 0.42
Цезий-137	24.7 / 1.0	14.9 / 1.0	12.2 / 1.0	16.8 / 1.0	54.5 / 1.0

н - концентрация радионуклидов ниже порога чувствительности используемого метода

С 5 мая 1986 г. к нам начали поступать данные о необычном радионуклидном составе загрязнения атмосферного воздуха с научно-исследовательских судов, выполнявших в это время текущие работы в Северной Атлантике. В частности, в табл.2 представлены результаты анализа проб атмосферного аэрозоля, полученные на борту НИС "Э.Кренкель" в процессе его движения с запада на восток вдоль параллели 50° с.ш. Из таблицы 2

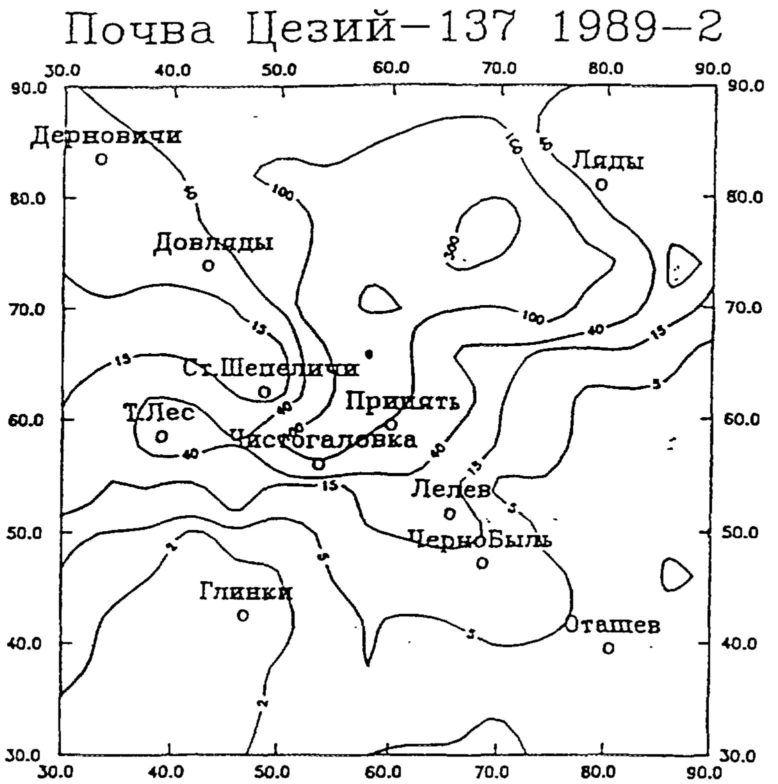

Рис.1. Плотность загрязнения почв 30-км зоны цезием-137 по данным реперной сети, октябрь 1989 г., Ки/км²
1 Ки/км² = $3.7 \cdot 10^4$ Бк/м²

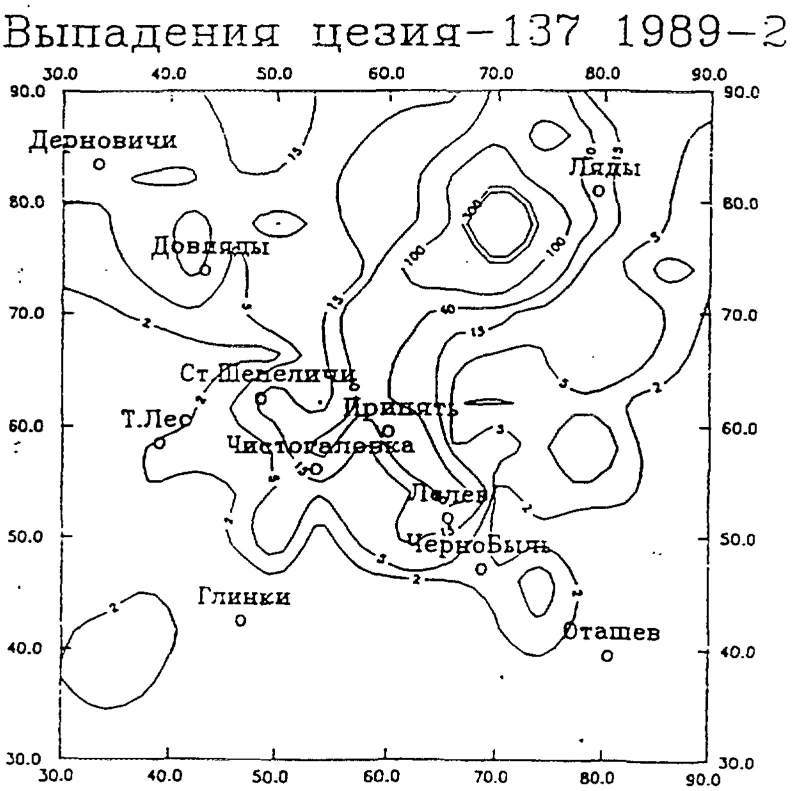

Рис.2. Плотность атмосферных выпадений цезия-137 на планшеты реперной сети в 30-км зоне, октябрь 1989 г., Бк/м²

очевидно, что в данном случае "чернобыльские" радионуклиды ограничены в основном всего шестью изотопами - Ru-103, I-131, Te-132, Ba-140, Cs-134 и Cs-137. При этом ведущую роль играют I-131, Te-132 и изотопы цезия. Таким образом при сопоставлении данных, полученных в ближней зоне ЧАЭС и в Северной Атлантике, становится очевидным, что можно ожидать при оценке загрязнения местности в дальней зоне. Такую информацию мы имели уже в мае 1986 года.

Второй пример имеет отношение к проблеме, имевшей большой общественный резонанс на Украине в первые месяцы после аварии. Это вопрос о возможности ветрового пылеподъема и вторичного переноса в атмосфере ранее выпавших на землю радионуклидов. Для количественной оценки этого эффекта был проведен грандиозный по своим масштабам геофизический эксперимент. В 60-км зоне вокруг ЧАЭС на площади в 11,5 тыс. $км^2$ по радиальной схеме было выставлено более 500 стандартных марлевых планшетов надетых на бетонные столбы высотой 1 м над землей. После месячной экспозиции планшеты подвергались радинуклидному анализу на полупроводниковых гамма-спектрометрах, а результаты анализа сравнивались с аналогичными измерениями проб почвы, которые отбирались рядом с каждым столбом. Такой эксперимент был проведен несколько раз. На рис.1 и 2 показаны результаты такого эксперимента, проведенного в октябре 1989 по цезию-137 в пределах 30км зоны. Из сопоставления данных, приведенных на рисунках следует, что для того, чтобы непрерывные выпадения цезия-137 привели к загрязнению, сравнимому с уже имеющимся загрязнением почвы в том же месте, потребуется 10^3 - 10^4 месяцев. Это означает, что горизонтальная миграция поля загрязнения за счет пылепереноса чрезвычайно мала($< 10^{-3} мес^{-1}$)

В итоге обобщения громадного количества накопленного матеериала по радионуклидному анализу проб атмосферного аэрозоля, природных вод и почвы, можно сделать следующие основные выводы о динамике поведения "чернобыльских" радионуклидов в природных средах:

1. Все радионуклиды, выброшенные в атмосферу в результате Чернобыльской аварии, по степени летучести делятся на следующие категории по степени убывания летучести:
высшая категория - ^{131}I, ^{132}Te, ^{133}I, ^{134}Cs, ^{136}Cs, ^{137}Cs; средняя категория - ^{103}Ru, ^{106}Ru, ^{140}Ba (^{140}La); "слаболетучая категория, в которую среди прочих входят ^{95}Zr, ^{95}Nb, ^{141}Ce, ^{144}Ce и все трансурановые радионуклиды (^{238}Pu, $^{239,240}Pu$, ^{241}Pu, ^{241}Am, ^{242}Cu, ^{244}Cu).

2. На пятнистость радиоактивных выпадений по территории Европы оказали основное влияние три фактора: (а) траектории распространения выбросов радиоактивности из реактора за время активной фазы аварии; (б) шероховатость и расчлененность поверхности по пути распространения радиоактивного облака и струи выброса; (в) дождевые осадки на пути распространения продуктов выброса.

3. В соответствии с категориями "летучести" радионуклидов на территории Европы радионуклидный состав сформировавшихся пятен имеет следующие характеристики. Центральное пятно, внутри которого располагается ЧАЭС, аккумулирует в себе практически все радионуклиды "слаболетучей" категории и большую часть средней категории. Все остальные пятна, среди которых наиболее значимыми являются Брянско-Гомельско-Могилевское и Калужско-Тульское, обусловлены радионуклидами высшей категории летучести и в меньшей степени средней категории.

4. Загрязнение поверхностных вод связано в основном с выпадениями радионуклидов на водную поверхность в процессе первичного атмосферного переноса радиоактивности. Поэтому кроме водоемов ближней (60-км) зоны, на поверхность которых выпал весь набор радионуклидов, остальные водоемы, в частности Брянско-Гомельско-Могилевского пятна,загрязнены радионуклидами высшей категории и в меньшей степени средней категории летучести.

5. Вторичное загрязнение поверхностных вод за счет смыва радиоактивности с территорий водоразделов в основном в

период дождевых паводков и весенних половодий не привело к существенному увеличению концентраций ^{134}Cs, ^{137}Cs, и ^{90}Sr в воде, т.к. определенные годовые модули смыва оказались малы: 0,1% для изотопов цезия и 0,5% для ^{90}Sr.

6. Как следует из п.5 горизонтальная миграция радионуклидов в почве за счет водного смыва незначительна. Законы вертикальной миграции в разного типа почвах и в разных ландшафтах оказались такими же, как при заглублении радионуклидов, выпавших после испытаний ядерного оружия.

XA9745872

CHERNOBYL FALLOUT RADIONUCLIDES IN SOIL, PLANT AND HONEY OF A MOUNTAIN REGION

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INTRODUCTION

Honey bee and the products (honey, pollen, wax, propolis) are generally considered as efficient bioindicators of the environmental pollution. Honey bee activity upon a territory is well defined both in space and time and honey bee itself is easier to control than other animal bioindicators (birds, fish, wild animals). Networks of bee hives near nuclear and industrial installations are therefore often used for environment pollution research and control (1,2).

The long-term radioactivity investigations in West Serbia (Mt.Tara) are a part of a project dealing with determination of natural and man made radionuclides in soil, meadow flora and honey (3,4). The region is a karst plateau with average height of 1280 m above the sea level, rich in pastures and meadows. Vegetation period is from May to the end of June. There are more than 290 plant species, 77 of them belong to meadow flora with high melliferous coefficient (1-4). The soil is uncultivated and can be divided in two groups: the one with dominant limestone and the other composed of shale rocks, althought mixed soil can be found too (5).

The investigations started in 1983/84. Gamma exposure and Cs-137 activity measurements provided information on "zero status" of the radioecological situation in the region. During the nuclear plant accident at Chernobyl in April 1986 and afterwoords through the year, over two hundred samples of honey, grass and meadow flora have been examined (6,7).

Investigations of the radioactivity in soils, meadow flora and honey in the region continued up to 1991 and afterwords. The vertical distribution of Cs-134 and Cs-137 in different soils provided data on the migration rate through soil and on concentration factors for different phases of the "soil-plant-honey" ecosystem (8).

MATERIALS AND METHOD

Samples of soil, plants and honey were collected on eight locations in the region: soils from location I (riverside), V and VIII were shale, locations II, IV, VI and VII were on limestone and soil on location III was mixed. All soils were uncultivated except the one from location VII.

Samples of soils (500 g) were taken from the surface and from the depth of 5,10 and 15 cm, dried on 105^{o}C, grinded and sieved. Samples of plants (meadow flora, grass, moss, lichen: 50 - 100g dry mass) were grinded and dried at room temperature, while samples of honey (200g) were measured in native state. Samples were weighted in standard Marinelli beakers or cylindric beakers (250 g).

Gamma exposure rates were measured 1 m above grass areas with nuclear instrumentation MZ-10 (Nucl.Inst.Vinca, GM detection system); total standard error of the method 5%.

Activity of the radionuclides was determined on a HPGe detector (ORTEC, rel.efficiency 20%) and a Ge(Li) detector (ORTEC, rel. efficiency 23%) by standard gamma spectrometry.

Energy calibration was performed with a set of standard point sources (COFFRET d'etalon Gamma ECGS-2,Sacle): Ba-133, Co-57,60, Cs-137 (activity 10^2 Bq, overall uncertainty 3%) for HPGe detector and with a point etalon source of Eu-152 (EGMA 3, activity 2.597 x 10^5 Bq, overall uncertainty 3 %).

Geometric efficiency for soil matrix in Marinelli beaker determined by a soil reference standard (National Office of Measures OMH, Budapest) spiked with a series of radionuclides (Na-22, Co-57,60, Y-88, Ba-133, Cs-137, activities 122 - 355 Bq, overall uncertainty 5%) and for samples in cylindric beaker by a reference soil standard (IAEA/SOIL6) with Cs-137 and Ra-226 (activity 58 Bq/kg and 93 Bq/kg, respectively, significance level 0.05). For plant matrix efficiency was determined by a secondary hay standard (SNLab, Stockholm), with Cs-137 and Cs-134 (1359 Bq/kg and 124 Bq/kg, respectively, overall uncertainty 10%). Geometric efficiency for honey matrix was determined by secondary standards for solid state matrices (9).

Counting time interval ranged from 40.000 - 300.000s. The background integral mean counts was under 1.7 imp/s. Total standard error of the method was 15%. Shauvenet criteria was applied for statistics analysis of the data. Gamma spectra were analysed on a IBM/PS2 computer, programme SPECTRAN-AT.

RESULTS AND DISCUSSION

Radioecological situation in the region before the nuclear accident at Chernobyl in 1986

Natural and man made radionuclides in soils, plants and honey were determined in 1983/84 and gamma exposure rates measured. Mean gamma exposure rate was 1.2 pC/kgs with variations of 10% for different locations; the value was higher than for the rest of the country: 0.72 - 1.08 pC/kgs.

The results of Cs-137 activity measurements in soil, meadow flora and honey are presented in Table I. Data are presented as "means $\pm$ standard deviation" within the samples from the same location or in the region, while "<" denotes variations higher than 100% when upper limit of the value is presented. LLD denotes "lower limit of detection" defined as $k^2 \pm 2LC$ (k-coefficient of normal distribution corresponding

Table I. Activity (Bq/kg) of Cs-137 in soil, meadow flora and honey

soil	meadow flora	honey
< 5	LLD	2.4±0.2

to confidence level of 95%, LC - critical level that depends on background photo peak counts. No significant variations in Cs-137 activity in soil or honey were found due to the type of soil or honey, while in meadow flora the activity was generally under detectable limits. Activity of Cs-137 in honey was for an order of magnitude higher than the activity of K-40 (18-25 Bq/kg).

Radioecological situation in the region during the Chernobyl accident April-May 1986 and through 1986

During the nuclear plant accident at Chernobyl(May '86), gamma exposures outdoors (altitude 1082 m) and indoors (in children summer houses, same altitude) in the region had been measured. Outdoor exposures were in the range from 2.56 - 3.66 pC/kgs, those indoors in the range 1.4 - 1.6 pC/kgs.

Activity of I-131, Cs-134,137 was determined in grass, plants and honey sampled in May-June and November-December 1986. Besides I-131, other short lived radionuclides were detected. In some samples of honey Ag-110m from the material used to bury the reactor was found, too (2 - 4 Bq/kg). Two hundred samples of honey, grass and meadow flora were examined. The results are presented in Table II, III and IV (in Bq/kg fresh grass, meadow flora or honey).

Table II. Activity (Bq/kg) of Chernobyl radionuclides in grass and meadow flora (May '86)

I-131	Cs-134	Cs-137	Ru-103	Ru-106
1630-2510	860-1360	1950-2940	2730-4310	890-965

Table III. Activity (Bq/kg) of Chernobyl radionuclides in honey

	I-131	Cs-134	Cs-137	Ru-103	Ru-106
May-June'86	3387±40	30±14	69±34	69±14	36±8
Nov.-Dec.'86	-	43±4	101±15	-	32±3

Table IV. Activity (Bq/kg) of short lived radionuclides in honey

Radionuclide	T1/2 (d)	May'86	December'86
Cs-136	13	0.1 - 0.8	< 0.3
Ba(La)-140	13	2 - 13	< 1
Zr-95	65	< 2	< 2
Nb-95	35.1	-	< 4
Ce-144	284	-	< 11
Ce-141	32.5	< 2	-
Rh-102	206	-	< 0.5

The results indicated that towards the end of the year the short lived radionuclides contributed about 6-10% in the total activity of honey (10).

Radioecological situation after the nuclear nuclear accident at Chernobyl, from 1987 to 1991

Radioactivity investigations in the region continued to 1993. Gamma exposure rate measurements in 1991 indicated two radioecological areas: on shale soils with higher exposure rates (2.32±0.10 pC/kgs) and on limestone with lower values (1.92±0.08 pC/kgs).

Activity of the Chernobyl radionuclides in honey, soils and plants was determined from 1987 to 1991. The results are presented in Table V, VI, VII and VIII.

Table V. Activity (Bq/kg) of Cs-137 in honey

1987	1988	1990	1991
3.2±0.2	2.4±0.4	2.4±0.4	2.1±0.1

Table VI. Activity (Bq/kg) of short lived radionuclides in honey

	Cs-134	Ru-106	Ce-144	Rh-102
1987	< 8	< 28	< 4	< 1
1988	< 3	< 20	< 4	-
1990	< 1	< 8	< 2	-

Ag-110m (< 0.6 Bq/kg) had been found in some samples of honey, too. Since 1988 no significant changes in Cs-137 content in honey had been observed.

The activity of Cs-137 in meadow flora from limestone soils was nearly three times higher than the one in samples from shale soils. In 1991 Cs-134 and Cs-137 were still found in high amounts in moss and lichen.

Table VII. Activity (Bq/kg) of Cs-137 in meadow flora

Soil	shale	limestone
	47±12	127±18

Table VIII. Activity (Bq/kg) of Cs-134 and Cs-137 in moss and lichen

	moss	lichen
Cs-134	808±169	1692±340
Cs-137	8196±1743	18236±2960

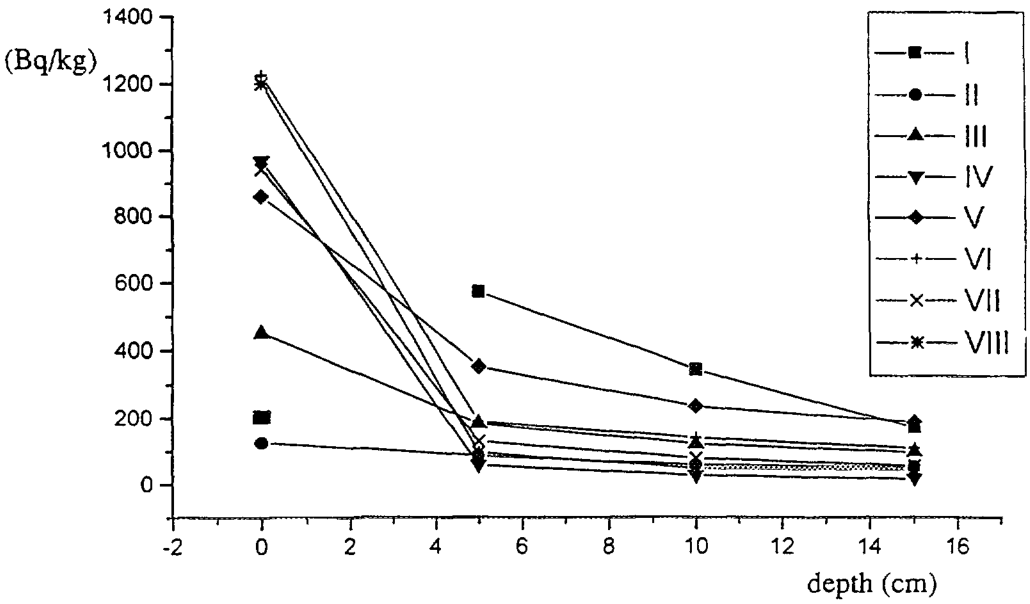

Fig. 1. Vertical distribution of Cs-137 in soil

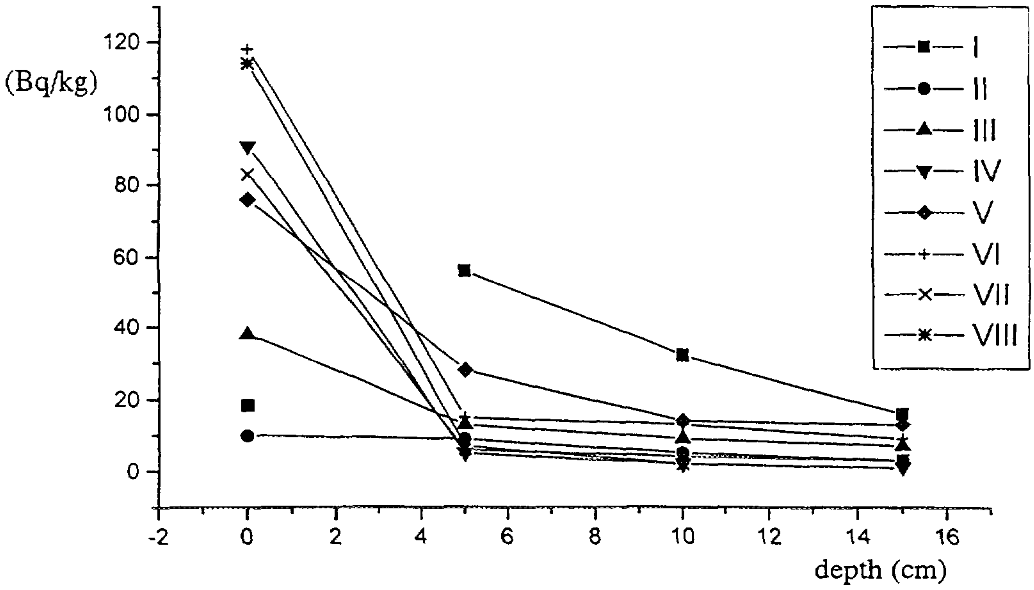

Fig. 2. Vertical distribution of Cs-134 in soil

The vertical distribution of Cs-134 and Cs-137 (surface, 5, 10, 15 cm) is presented in Fig.1 and 2. The results indicate slow migration through soils, except on riverside.

The concentration factors defined as ratios of activity in plant to soil, honey to plant and honey to soil has been calculated. The results are presented in Table IX. Cs-137 concentration in plants strongly depends on soil type, but not its concentration in honey .

Table IX. Concentration factors for Cs-137

Soil	soil/plant	honey/plant	honey/soil
shale	0.1	4.5×10^{-2}	4.5×10^{-3}
mixed	0.6	2.0×10^{-2}	1.3×10^{-3}
limestone	1.8	1.6×10^{-2}	2.9×10^{-3}

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XA9745873

RESULTS OF TEN YEARS STUDY OF CHERNOBYL NPP RELEASE FALLOUT PROPERTIES AND BEHAVIOUR IN SOILS

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1. INTRODUCTION

Radioactive contamination of territories of Ukrainian and Belorussian Polesye as a result of ChNPP accidental release is characterized by high level of un-homogenity of fallout properties (physico-chemical properties, radionuclide composition etc.), density of the territory contamination by long-lived radionuclides. On the other hand, the soil-plant cover of contaminated territory is presented by large set of soils, characterized by contrast physico-chemical and water-physical properties.Peculiarities of the behaviour of different radionuclides, represented initially by various components of radioactive fallout, in soils, as a first link of migration chains are considered.

2. METHOD

The agreed-upon radioecological, radiochemical, soil-chemical and other methods of investigations have been used: *in situ* observation as well as a model laboratory experiments for the estimation of intensity and possible mechanisms of radionuclides vertical transfer; sequential extraction procedures and isotopic dilution method for estimation of the dynamics of radionuclides mobile forms in soils; α- and γ-spectrometry, autoradiography, track-radiography and other nuclear-physical methods for study of properties and radionuclide composition of ChNPP release fallout and their transformation in soils, etc.

Experimental sites for *in situ* observation were choosen with taking into account the following criteria:

- landscape-geochemical conditions, including physico-chemical propertes, granulometric and mineralogical composition of soils;
- physico-chemical properties of fallout (ratio of fuel and condensed components) at various tracks;
- density of the territory contamination by long-lived radionuclides;
- type of lands (natural and improved meadows, fallow lands, agricultural lands).

Most typical soils, represented the soil cover of contaminated territory of Ukraine have been used in model experiments.

3. RESULTS

3.1. Feature of fallout

Survey of the contaminated territories, carried out during the first months after the accident, has shown the great unhomogeneity of soil-plant cover radioactive contamination as well as ununiformity of fallout radionuclide composition (activity and isotopic ratio of ^{95}Zr-^{95}Nb, ^{140}Ba-^{140}La, ^{103,106}Ru, ^{141,144}Ce, ^{134,137}Cs et al) at various tracks of fallout. The presence of hot particles in fallout was shown by the autoradiography of tree leaves.

The further research demonstrated obviously enough that the radioactive fallouts are presented mainly by two components (fuel and condensed ones), contamination of the territory is a superposition of the mentioned components tracks, components ratio depends on the direction and the distance from ChNPP [1,2].

The territories of the "remote" tracks of fallouts are characterized by contamination with condensed component, represented mainly by radioisotopes of Iodine, Caesium and, particularly, Ruthenium. According to their physico-chemical properties these fallouts are similar to global ones [3].

The territories of the "close-in"tracks of fallouts (R<50-60 km) are characterized by the contamination with the superposition of condensed and fuel components of fallout's. The latter is represented small particles of high burn-up uranium oxide fuel with composition similar to that of the fuel in the reactor core but with some depletion of the radioisotopes of more volatile chemical elements (iodine, ruthenium and caesium), some particles were spherical, others were angular shards. Apart from uranium oxide and fission products, many hot particles also contained zirconium and traces of iron, molybdenum, nickel, copper, zinc, silica, aluminium and lead. Within the ChNPP 30-km zone fuel particles were estimated to account for more than 75% of the total radioactive contamination on the ground. Essentially all the radiostrontium and plutonium were associated with particles at the time of deposition.[1,2,4].

Some physico-chemical and nuclear-physical properties of "chernobyl" fuel particles (radionuclide, substantial and granulometric composition, burn-up etc.) have estimated. Data on experimental relationship between i-th radionuclide's activity and ^{144}Ce activity in the fuel particles at the time of the accident are shawn in Table I [5].

TABLE I. Experimental relationship between i-th radionuclide's activity (A_i) and ^{144}Ce activity ($A_{144\,(FHP)}$) in the fuel particles at the time of the accident

Radionuclide	$A_i/A_{144\,(FHP)}$	Radionuclide	$A_i/A_{144\,(FHP)}$
^{90}Sr	0.05	^{137}Cs	0.04
^{95}Zr	2.3	^{141}Ce	1.34
^{103}Ru	1.08	^{144}Ce	1.0
^{106}Ru	0.26	^{154}Eu	0.0015
^{125}Sb	0.006	^{155}Eu	0.0017
^{134}Cs	0.02	$^{239,240}Pu$	0.0004

The fraction of radionuclides, initially contained in fuel particle matrix, in total activity of these ones in soils at the moment of accident, using the data on soil contamination with refractory radionuclides (^{144}Ce etc., taking into account the radioactive decay) can be estimated by the following equations [5] :

$$q(^{137}Cs)=(^{137}Cs/^{144}Ce)_{FP}/(^{137}Cs/^{144}Ce)_{soil}=0.04/(^{137}Cs/^{144}Ce)_{soil}$$

$$q(^{90}Sr)=(^{90}Sr/^{144}Ce)_{FP}/(^{90}Sr/^{144}Ce)_{soil}=0.05/(^{90}Sr/^{144}Ce)_{soil}$$

3.2. Transformation of fallout in soils

Study of the dynamics of fallout transformation in soils has been carried out with the use of sequential extraction techniques, isotopic dilution method, ultrafiltration, dialysis etc. In general, content of ^{137}Cs exchangeable forms in soils is decreasing with time, different decrease rate is noted for conditions, characterised by different soils conditions as well as various initial forms of fallout (ratio of fuel component of fallout to condensed one). Significantly lower content of radiocaesium exchangeable forms as well as higher intensity of its decrease is noted for groups of hydromorphous soils, characterised by higher value of CEC and higher content of clay minerals [6]. However, this phenomena is not an absolute one and has some exceptions. Increase of the content of ^{137}Cs exchangeable forms in soils of some meadows in 30-km since 1990-1991 and its further decrease have been observed [6,7]. It should be noted also that less content of radiocaesium in soils of ChNPP immediate zone is connected not with high content of fuel component in fallout only, but with high sorption by solid phase of hydromorphous soils also.Content of radionuclides fractions, less strongly binded with soils solid phase components, decreases with time. Rate of decrease depends both on radionuclides initial physico-chemical forms of fallout and on soils properties [7].

Comparison of the data on radiocaesium mobile forms in mineral and organic soils with radionuclide transfer factor from these soils to plants allows to make a conclusion about the impossibility of the direct use of mentioned data for the prediction of radiocaesium biological availability. However, the information on radiocaesium mobile forms content in soils could be used as a criteria of its state dynamic in soils.

Dynamics of the content of radiocaesium exchangeable forms in soils depends on above-mentioned factors.

Presence of the fuel particles in the fallout of Chernobyl accidental release has modified the including intensity of the radionuclides, represented by fuel component, to migration chains in terrstrial ecosystems. The mentioned modification depends on both the climatic conditions and on the fuel particles properties [2-4].

The latest data, obtained in 1993-1995, demonstrate, that in some soils there is high quantity of undestructed fuel particles (up to 60-80% in accordance to the data of autoradiography and assessments of the content of ^{90}Sr ion-exchangeable forms in soil).

Significant dependence of the dissolution velocity of fuel particles on the level of physico-chemical transformation of particles matrix (incinerated or non-incinerated fuel; particles, subjected to leaching in soil in natural conditions, etc.) and characteristics of the media (pH, RedOx-potential etc).is shown in model experiments.

3.3. Radionuclides transfer in soils

Close intensity of vertical transfer of different radionuclides (^{144}Ce, ^{90}Sr, $^{134,137}Cs$ et al) in soils on "fuel" tracks of fallout during first 2-3 years after the accidental release has been observed. Later the separation of radionuclides, differing in their physico-chemical properties, in soil profiles has been found. Abnormally high migrative ability of Caesium radioisotopes in hydromorphous organic soils has been observed.

Dynamics of the vertical transfer parameters of ChNPP release radionuclides in soils, calculated with use of the convective-diffusional and quasi-diffusional models of transfer, is discussed. Values of ^{137}Cs quasi-diffusion coefficient vary from $(1\text{-}4)\cdot10^{-9}$ cm^2c^{-1} for mineral automorphous soils (soddy-podsolic loamy-sand, grey soils etc) to $2\cdot10^{-8}$ cm^2c^{-1} and higher for organic hydromorphous soils (peaty-boggy, peaty and similar).

Parameters of diffusional and directional transfer of ^{90}Sr and ^{137}Cs in initial water-soluble form as well as directional transfer of fuel particles in some soils, typical for the Ukrainian Polesje, was studied in model column experiments. It was shown that diffusion coefficients of radionuclides, depending of soils moisture content vary in a following limits: ^{90}Sr - soddy-podzolic sandy soil (SS): $(2.1\text{-}5.1)\cdot10^{-7}$ cm^2c^{-1}, soddy-podzolic loamy-sand soil (LSS): $(1.0\text{-}1.7)\cdot10^{-7}$ cm^2c^{-1}, peaty soil (PS): $(0.06\text{-}1.3)\cdot10^{-7}$ cm^2c^{-1}; ^{137}Cs - soddy-podzolic sandy soil: $(0.5\text{-}1.8)\cdot10^{-8}$ cm^2c^{-1}, soddy-podzolic loamy-sand soil: $(0.9\text{-}1.4)\cdot10^{-8}$ cm^2c^{-1}, peaty soil: $(0.17\text{-}1.3)\cdot10^{-8}$ cm^2c^{-1} (Table II). The rate of directional transfer of fuel particles is much lower than that for radionuclides, introduced in soil column in the

TABLE II. Diffusion coefficients of ^{137}Cs, ^{90}Sr and ^{239}Pu in different soils, depending on their moisture content

Soil	Radionuclide	$D^a\cdot10^{-8}$, $\cdot cm^2/c$ with moisture content, % of total moisture content		
		30	60	100
SS	Strontium-90	20.0±1.0	26.0±3.0	35.0±5.0
LSS	Strontium-90	9.0±1.0	16.0±3.0	15.0±1.0
PS	Strontium-90	0.6±0.1	3.7±0.2	13.0±1.0
SS	Caesium-137	0.50±0.04	0.70±0.15	0.9±0.4
LSS	Caesium-137	0.8±0.1	1.0±0.1	1.7±0.5
LS[b]	Caesium-137	n/determ.	n/determ	0.28±0.08
ChL[b]	Caesium-137	0.27±0.10	0.63±0.20	n/determ.
PS	Caesium-137	1.7±0.3	7.9±3.0	31.6±5.0
LSS	Plutonium-239	0.081±0.020	0.077±0.023	0.19±0.03
ChL	Plutonium-239	0.067±0.022	0.069±0.07	n/determ.
LS	Plutonium-239	n/determ.	n/determ.	0.086±0.020

[a]D - diffusion coefficient; [b]LS - soddy-podsolic loamy soil; [b]ChL - loamy chernozem.

water-soluble form. Values of the effective quasi-diffusion coefficient of fuel particles with real size distribution on 1988 (place of sample selection - R=3 km, W) are: for soddy-podzolic sandy soil: 3.0 $\cdot 10^{-10}$ cm^2c^{-1}, for soddy-podzolic loamy-sand soil: 4.0 $\cdot 10^{-10}$ cm^2c^{-1}, for peaty soil: 2.3 $\cdot 10^{-10}$ cm^2c^{-1}. Values of transfer parameters of Plutonium isotopes are closer to those for ^{137}Cs and are depend on destruction level of fuel in particular soil conditions.

Classification of Ukrainian Polessye soils according to migrative mobility of ^{137}Cs in these ones was proposed.

3.4. Modelling and forecast

Mathematical model of radionuclides transfer in soil profile is developed. Model allows to take into account the role of physico-chemical forms of radioactive fallout, of various forms of radionuclide transfer in soil profile (radionuclides in the matrix of fuel particles; radionuclides in soil solution in the form of free ions and complex compounds; sorbed form of radionuclides) and their transformation in the redistribution of radionuclides in soil profile [8].

$$\frac{\partial C_1(x,t)}{\partial t} = \frac{\partial}{\partial x}\left[D(x,t)\frac{\partial C_1(x,t)}{\partial x}\right] - V(x,t)\frac{\partial C_1(x,t)}{\partial x} - \left(b(x,t)+g(x,t)\right)C_1(x,t) - \frac{b(x,t)C_1(x,t)}{K_d(x,t)} + a(x,t)C_4(x,t) - \lambda C_1(x,t)$$

$$\frac{\partial C_2(x,t)}{\partial t} = \frac{\partial}{\partial x}\left[D(x,t)\frac{\partial C_2(x,t)}{\partial x}\right] - V(x,t)\frac{\partial C_2(x,t)}{\partial x} + g(x,t)C_1(x,t) - \lambda C_2(x,t)$$

$$\frac{\partial C_3(x,t)}{\partial t} = b(x,t)\left(C_1(x,t) - \frac{C_3(x,t)}{K_d(x,t)}\right) + \lambda C_3(x,t) \qquad (1)$$

$$\frac{\partial C_4(x,t)}{\partial t} = \frac{\partial}{\partial x}\left[D_4(x,t)\frac{\partial C_4(x,t)}{\partial x}\right] - (a(x,t)+\lambda)C_4(x,t)$$

where: $C_1(x,t)$ - concentration of radionuclide in soil in the form of free ions at the depth x at the moment t; $C_2(x,t)$ - concentration of radionuclide in soil in the form of soluble complex compounds at the depth x at the moment t; $C_3(x,t)$ - concentration of sorbed radionuclide forms in soil at the depth x at the moment t; $C_4(x,t)$ - concentration in soil of radionuclide in fuel particles at the depth x ast the moment t; $D(x,t)$ - effective diffusion coefficient of soluble forms at the depth x at the moment t; $V(x,t)$ - effective velocity of convective transfer of radionuclide with soil moisture at the depth x at the moment t; $D_4(x,t)$-effective diffusion coeffiecient of fuel particles at the depth x at the moment t; $b(x,t)$ - intensity of sorption of soluble radionuclide forms by soil at the depth x at the moment t; $a(x,t)$ - intensity of fuel particles festruction at the depth x at the moment t; λ - constant of decay. Total concentration of all considered radionuclide forms in the soil layer $C(x,t)$ is described by the ratio:

$$C(x,t) = C_1(x,t) + C_2(x,t) + C_3(x,t) + C_4(x,t).$$

The example of model application for the calculation of predictive assessments of ^{90}Sr, ^{137}Cs and $^{239,240}Pu$ redistribution in the profile of soddy-podzolic sandy-loamy soil on the fuel track of ChNPP fallout (fallow land), is presented below (Fig....., Tables). Fallout characteristics: ~100% of ^{90}Sr and $^{239,240}Pu$ and about 80% of ^{137}Cs were within fuel particles. Parameters were estimated with the condition that the values of V, D_4 and a are the same for all radionuclides. The values of the mentioned parameters are estimated as follows: V=0.86±0.02cm/year, D_4 =0.06±0.02cm^2/year and a=0.06±0.01 1/year. The values of other parameters are presented below.

TABLE III. Parameters of transfer model

Radionuclide	D, cm^2/year	b, 1/year	g, 1/year	K_d cm^3/g
^{90}Sr	30±7	0.4±0.3	2.4±1.2	10
$^{239,240}Pu$	12.9±3.7	0.87±0.25	0.06±0.04	550
^{137}Cs	11.4±0.6	24.0±0.3	0.58±0.03	300

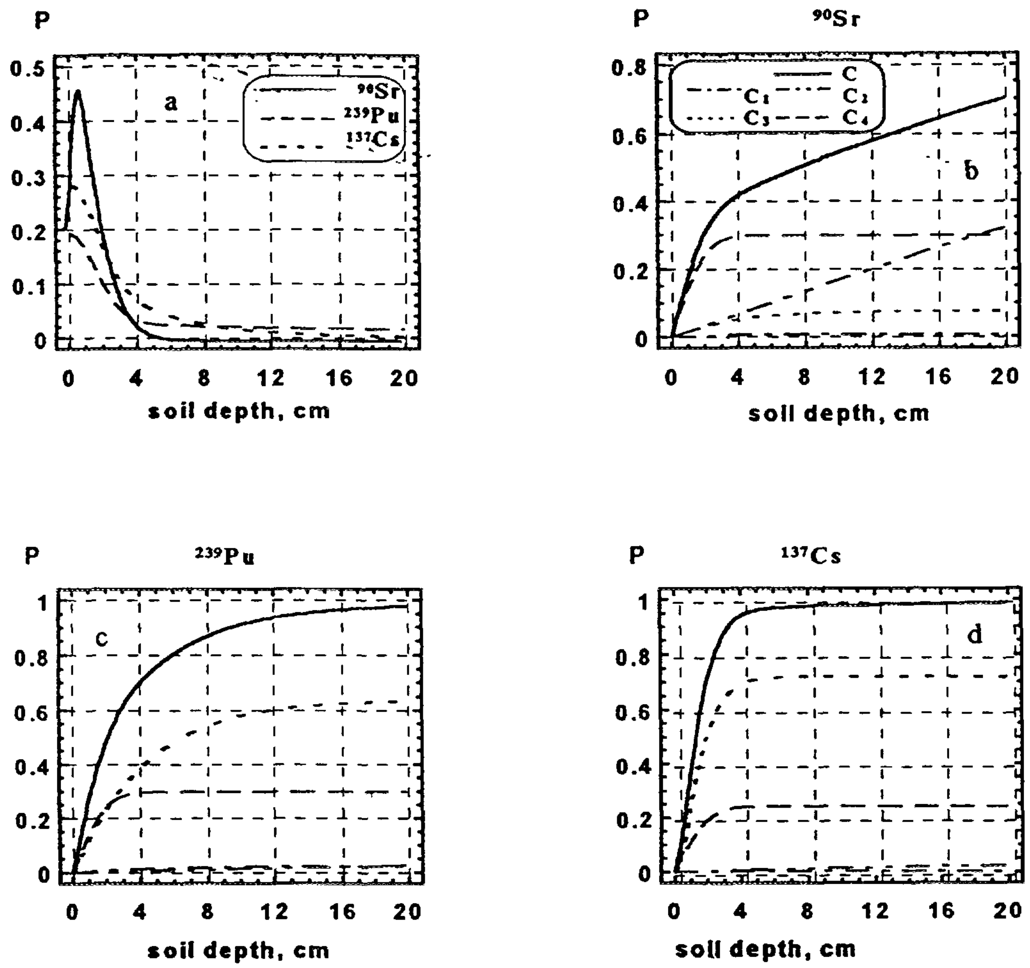

Fig.1 Forecast (on 2006) of the distribution profiles P(x,t) of ^{90}Sr, ^{239,240} Pu and ^{137}Cs in soddy-podsolic loamy-sand soil: a - total distribution (differencial curve); b, c, d - distribution profiles of considered forms of radionuclides transfer (integral curve)

Fig.1 demonstrates in differential form predictive (for 2006) profiles of distribution P(x,20) of ^{90}Sr, ^{239,240} Pu and ^{137}Cs in the soil of the plot (gross content of a specific radionuclide), on Figures 2b, 2c and 2d (for ^{90}Sr, ^{239,240} Pu and ^{137}Cs, respecttively) the profiles of distribution in soil of the considered within the model forms of radionuclides transfer are presented in integral form. Below the predicted values of ablsolute portions of various forms of radionuclides transfer, included to the transfer model, are presented (Table IV).

TABLE IV. Predicted values of ablsolute portions of various forms of radionuclides transfer, included to the transfer model

Form of radionuclide	^{90}Sr	^{239,240} Pu	^{137}Cs
Ion-exchangeable, C1	0.62	0.04	0.035
Watersoluble complex compounds, C2	0.008	0.02	0.003
Sorbed forms, C3	0.072	0.64	0.721
Fuel particles, C4	0.30	0.30	0.241

TABLE V. Migration ability of ^{137}Cs in typical soils of Ukrainian Polesye

Soils	Granulometricc omposition	M^a, $\cdot 10^{-8}$ $cm^2 \cdot s^{-1}$	D^b, $\cdot 10^{-8}$ $cm^2 \cdot s^{-1}$	$V_k{}^b$ $\cdot 10^{-8}$ $cm \cdot s^{-1}$
Organic hydromorphous soils (peat-boggy, peaty etc.)		> 2.0	0.5 - 1.2	0.3 - 1.0
Meadow gley and gleed, meadow and soddy carbonate, soddy gley and gleed	sandy	1.5 - 2.0	0.3 - 0.8	0.3 - 1.7
Soddy gley and gleed	sandy-loam, loamy-sand	1.0 - 1.5	0.8 - 1.0	0.2 - 0.5
Soddy-podsolic, soddy-podsolic gley, weakly humous sand	sandy	0.4 - 1.0	0.3 - 0.7	0.3 - 0.5
Soddy-podsolic, grey podsoled etc.	sandy-loam, loamy-sand, loamy	< 0.4	< 0.4	0.1 - 0.3

[a] - M - quasi-diffusion coefficient, calculated by one-component model of transfer; [b] - D, V_k - diffusion coefficient and directional transfer velocity, respectively, calculated by convective-diffusional model of transfer.

TABLE VI. Effective half-time of ^{137}Cs residence in upper layers of soils

Soils	Granulometric composition	Effective half-time of ^{137}Cs residence in upper layers of soils $T_{1/2}$(0-2 cm)	$T_{1/2}$(0-5 cm)
Organic hydromorphous soils (peat-boggy, peaty etc.)		5.5 ± 0.8 / 4.0 - 9.0	14.9 ± 1.7 / 11.2 - 21.6
Meadow gley and gleed, meadow and soddy carbonate, soddy gley and gleed	sandy	5.1 ± 1.3 / 3.2 - 11.0	12.7 ± 2.7 / 8.3 - 24.3
Soddy gley and gleed	sandy-loam, loamy-sand	6.6 ± 0.4 / 5.6 - 7.9	17.8 ± 0.8 / 15.7 - 20.3
Soddy-podsolic, soddy-podsolic gley, weakly humous sand	sandy	8.3 ± 0.7 / 6.7 - 11.0	20.3 ± 1.1 / 17.5 - 24.3
Soddy-podsolic, grey podsoled etc	sandy-loam, loamy-sand, loamy	11.1 ± 0.5 / 10.0 - 12.7	24.4 ± 0.3 / 23.0 - 26.0

Results of *in situ* observation of ^{137}Cs vertical re-distribution in soils profile at various tracks of fallout in combination with results of the model experiments are permitted to classify the soils of contaminated territory of Ukrainian Polesye according to migration ability of radiocaesium (Table V). From point of view of migration ability most "critical" are the hydromorphous organic soils of Ukrainian Polesye.

Some forecast assessments of radionuclides transfer in soils are calculated (ecological and effective half-time of the residence in upper layers of soils, dynamics of internal dose rate, formed by Caesium radioisotopes etc.- Table VI, Fig.2). Values of the effective half-time of ^{137}Cs and ^{90}Sr residence in upper 5-cm layer of undisturbed soils vary, respectively, from 8-14 and 20-22 years for organic hydromorphous soils to 20-22 and 6-8 years for mineral automorphous soils, the same parameters for ploughed layer of disturbed soils are, respectively, 16-18 and 24-26 years for organic hydromorphous soils and 22-24 and 12-14 years for mineral automorphous soils.

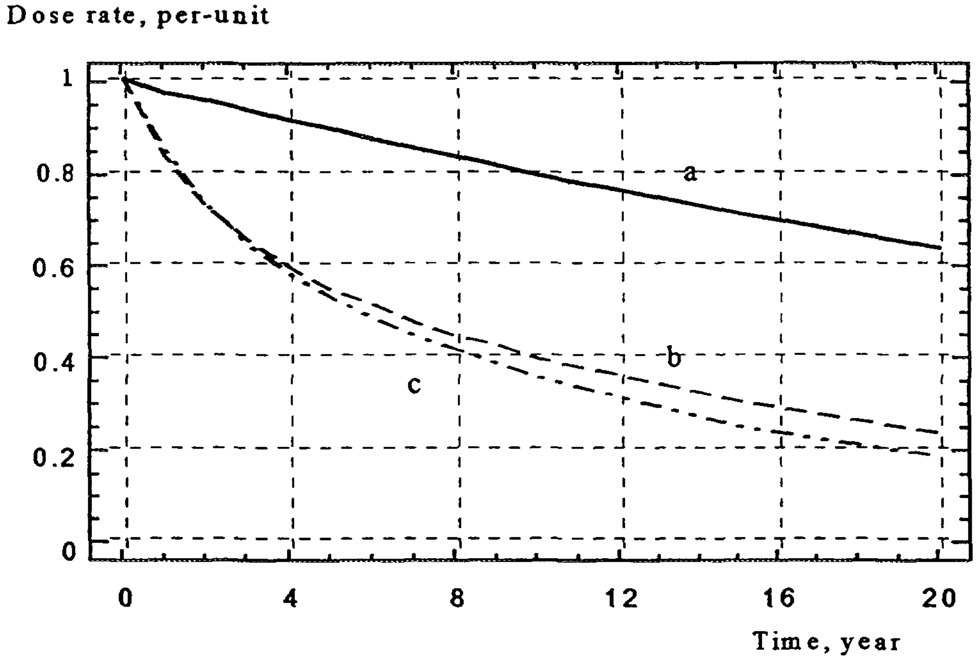

Fig.2 Calculated curves of dynamics of gamma-irradiation dose rate, formed by ^{137}Cs, under soil surface (H=1 m): a - without consideration of radionuclide vertical transfer; b, c - with consideration of radionuclide vertical transfer: b - in soddy-podsolic sandy-loam soil; c - in peaty soil.

Comparable assessments of the intensity of ^{137}Cs vertical transfer in soils and half-life of this radionuclide were demonstrated.

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RADIOLOGICAL SITUATION ON PRIVATE FARMS AFTER THE ACCIDENT AT THE CHERNOBYL NUCLEAR POWER PLANT

XA9745874

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MATERIAL AND METHODS

Cesium-137 concentration in the samples was measured by means of gamma-spectrometer Nokia LPA 4900 with germanium-lithium detector. The samples of foodstuffs were taken from the typical families of Ukrainian Polessye, which consist of 3-4 adults and 2-3 children below 16.

DATA

According to the statistical data, land-use structure in Polessye, both on private and collective farms, varies in the ratio of arable lands and natural pasture: for collective farms - 1:2 - 2:1; for private farms - 1:5 - 1:10.

The decrease of Cs-137 content in milk is the result of Cs-137 binding by the soil absorption complex and application of countermeasures. These two processes provided the 10-20-fold decrease of Cs-137 content in milk on collective farms 987 to 1994, while on private farms it was only 4-6-fold decrease. Therefore Cs-137 activity in the flux with milk from private farms is about 80% , and from collective farms - only 20% of Cs-137 activity in all milk, produced in the regions. (Table 1).

The data from Table 2 also testify that the activity of Cs-137 in milk and meat from private farms is several times higher than from collective farms.

Another peculiarity of the diet of Polessye inhabitants is high consumption of mushrooms and berries. The content of Cs-137 in mushrooms in various Polessye regions varies from 800 to 32000 Bq/kg (Table 3). As a result, Cs-137 intake with mushrooms will vary as well. In 1994-1995 detailed analysis of this radionuclide intake with various components to the diet of a family in "Khliborob" collective farm, Dubrovitsa district, Rovno region, was carried out . It was found that the people in the families from the villages at a distance 3-5 km will have great differences in Cs-137 intake with various components of the diet. The population of Milyachy village, which consumed milk (Cs-137 content in milk 80-110 Bq/l). produced on the pastures with countermeasures, received 49% if Cs-137 with milk and 6% with mushrooms; without countermeasures - 63% with milk (230-550 Bq/l in milk) and 11% with mushrooms.

In the villages Velyun and Zagreblya (Cs-137 content in milk 14-30 Bq/l) 13-15% of Cs-137 is received with milk and 21-26% with mushrooms).(to remove)

The data of sociological survey demonstrated that the population of investigated villages can be divided into 3 groups by the consumption of forest products: pensioners, workers of the collective farm and forestry workers. Forestry workers are the critical group, which consume twice as many mushrooms as the workers of the collective farm. Besides, forestry workers make hay in the forest (Cs-137 activity in hay is 10000-15000 Bq/kg), and in winter the content of Cs-137 in milk during a certain time was 300-450 Bq/l. After the replacement of hay produced in the forest by the hay from the cultivated field of the collective farm (Cs-137 activity in the hay is 800 Bq/kg) content of Cs-137 in milk decrease to 45 Bq/l, and relative intake of Cs-137 with milk to the diet of a family decreased from 80 to 55%.

Tablè 1. Cs-137 fluxes with milk from private and collective farms

Number of cows in the villages where the milk contamination in private farms is >110 Bq/l	Milk production, tons	Cs-137 concentration, Bq/l	Cs-137 flux, kBq/year	Cs-137 flux, %
Volyn region				
Private 7748	186	140	2603328	80
Collective 6500	162	40	662000	20
Zhitomir region				
Private 13389	321	120	3856032	97
Collective11510	228	35	1007125	21
Rovno region				
Private - 21475	515	175	9109500	82
Collective - 20320	508	40	2032000	18
Chernigov region				
Private - 360	8.6	110	95040	80
Collective - 485	12.1	20	24250	20
Kiev region				
Private - 224	5.4	140	75264	57
Collective - 385	9.6	60	57750	43

Table 2. Content of Cs-137 in milk and meat of private and collective farms in 1995, Bq/kg

Region	District	Milk		Meat	
		Private farms	Collective farms	Private farms	Collective farms
Zhitomir	Emilchensk	90-240	40-70	30-120	10-70
	Novovolynsk	30-100	30-60	50-180	50-170
	Luginsk	60-500	20-150	100-500	100-300
	Olevsk	140-900	60-300	170-500	100-300
	Korosten	40-500	80-200	40-220	40-901
	Ovruch	30-260	40-200	80-400	100-320
Rovno	Dubrovitsa	14-500	30-70	80-330	40-110
Kiev	Polesskoye	60-190	50-80	70-250	50-130

Table 3. Content of Cs-137 in mushrooms and berries in Zhitomir and Rovno regions in 1995, Bq/kg

Region	District	Forest berries	Fresh mushrooms
Zhitomir	Emilchensk	1000-1800	1800-3500
	Novovolynsk	800-1600	80-1600
	Luginsk	500-8000	1300-3400
	Olevsk	1000-2700	3700-5000
	Korosten	1000-3500	2600-5000
	Ovruch	1000-2500	2000-4000
Rovno	Dubrovitsa	800-4500	5000-32000

CONCLUSION

Cs-137 intake to the diet of a family in Polessye depends mainly on the content of Cs-137 in the diet of cows and amount of mushrooms consumed by a family.

In order to reduce the intake of Cs-137 by human organism it is necessary to provide the local population with concentrated fodder and sorbents and to exclude contaminated fodder from the diet of cows. In the settlements, where after the application of countermeasures on the pastures relative intake of Cs-137 with milk is less than with mushrooms, the inhabitants should be informed by the radio and local newspapers about the most contaminated areas of collecting mushrooms and about the species of mushrooms with the highest accumulation coefficients of this radionuclide from soil.

Countermeasures, applied in agriculture of Ukraine, have permitted almost completely excluding production of food with the concentration of radionuclides exceeding set norms by 1992. At the same time, in the private sector radiation situation is much graver. This is associated with the difficulty of excluding usage for natural and seminatural ecosystems, from hay-mowing and pasturing especially in the regions with peatbog soils.

When organizing countermeasures it is necessary to distinctly fulfill such task: supply of urban population with clean products and supply of rural population, producing this food, with clean products too. If for the first category the countemeasures are directed mainly to the reduction of the collective irradiation dose (at least in the second period), for separate critical groups of rural people even 10 years after the accident the problem of preventing the excess of the permissible individual irradiation dose still exists.

XA9745875

RADIOLOGICAL MAP OF POLAND AFTER THE CHERNOBYL ACCIDENT (1988-1995)

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Introduction

Our investigations has been performed in the frame of Polish environmental monitoring system. At Central Laboratory for Radiological Protection, Dosimetry Department a project on „Radiological map of Poland" has been realized since 1988. The measurements and soil sampling were carried out in 1988, 89, 90 and 92 in 340 points located all over Poland using the net of meteorological stations of the Institute of Meteorology and Water Management. In 1994 the number of these points was reduced to 69.

Our investigation give the following possibilities:
- to create the base of computer-stored radiological data for the whole country.
- to obtain a set of radiological maps of Poland.

Methods and measurements

At each point were performed gamma radiation dose measurements. In the same sites soil samples were collected to determine concentration of the natural radionuclides and cesium isotopes by means of spectrometric analysis. Gamma dose rate was measured using three thermoluminescent detectors sets mounted 1 m above the earth surface. The annual gamma dose was calculated on the basis of measurements carried out in two six-month periods. Each sample of soil from the 10 cm surface layer was taken by a knife-edge pipe in six points laying at the circumference of a circle of 2 m radius and in the centre of the circle. The measurements of the radionuclide concentrations in soil samples were made using spectrometers with HPGe detectors located in low-background lead shielding houses. The time of each measurements was 60 000 s. The program of environmental investigations also included measurements performed in selected places using our mobile radiometric laboratory. These measurements were carried out by means of high pressure ioniziation chamber and an „in situ" method using portable spectrometer with a HPGe detector.

Results

The results can be presented in form of maps produced in „Sinus" or circle cartodiagram systems. The program „Sinus" extrapolates 340 results of the point measurements to the closest vicinity covering the whole area of Poland. The circle cartodiagram program merely visualizes results of the investigations in the very measurements and sampling points.

The mean gamma dose rate of the outdoor radiation in 1989 in Poland was 45.4 $nGy \cdot h^{-1}$ (without cosmic radiation). The values for individual measurement points range from 17.7 to 97.0 $nGy \cdot h^{-1}$.

The contribution of each radionuclides to external radiation dose rate can be calculated on the basis of spectrometric measurements of the soil samples. For instance, at the points in which ^{137}Cs concentration are the highest in Poland, the gamma dose rate due to cesium isotopes was twice as much as the gamma dose rate due to natural isotopes. These results were confirmed by „in situ" measurements.

The mean values and range of ^{134}Cs and ^{137}Cs concentration in the soil in Poland in 1988-1992 are presented in Table I.

Table I ^{134}Cs and ^{137}Cs concentration in the surface layer of soil in Poland in 1988-1992

Isotope	Concentration [$kBq \cdot m^{-2}$]			
	Year.			
	1988	*1989*	*1990*	*1992*
^{134}Cs	**0.99** 0.03 - 20.07	**0.72** 0.04 - 8.99	**0.51** 0.02 - 6.82	**0.25** 0.01 - 3.38
^{137}Cs	**4.67** 0.21 - 81.00	**4.68** 0.74 - 57.79	**4.72** 0.76 - 54.49	**4.24** 0.51 - 49.9

Map in „Sinus" system in the Fig. 1 shows ^{137}Cs concentration in 1988, for the 10 cm thick surface layer of the soil. Distribution of the average annual gamma dose rate due to natural and artificial radionuclides in the area of Poland in 1989 is presented in Fig. 2. Changes of ^{134}Cs and ^{134}Cs mean concentration in: 1988-1992 for 340 sampling points are presented in the Fig. 3. Our investigation performed in 1988 - 1995 revealed that cesium still appears, mainly in upper 10 cm surface layer of soil.

Contribution of different radiation sources to the annual effective dose equivalent to average individual in Poland in 1991 is given in Fig. 4. The value of the total effective dose equivalent of ionizing radiation to which statistic inhabitant in Poland was exposed was 3.6 mSv [1].

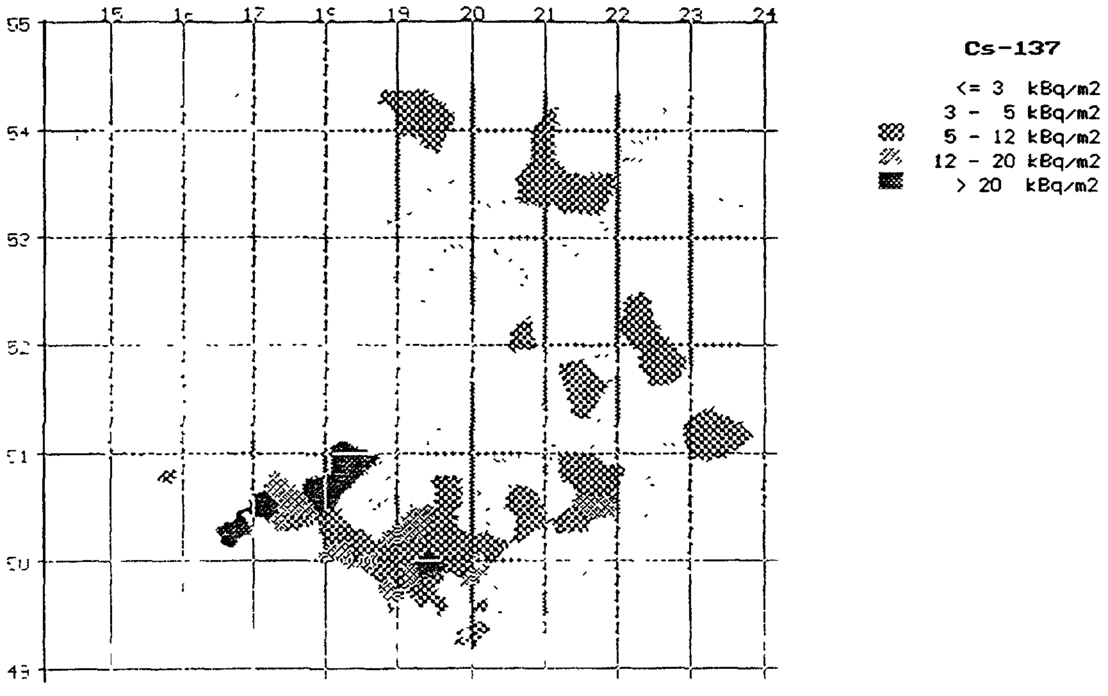

Fig. 1. ^{137}Cs concentration in Poland in 1988 for the 10 cm thick surface layer of the soil.

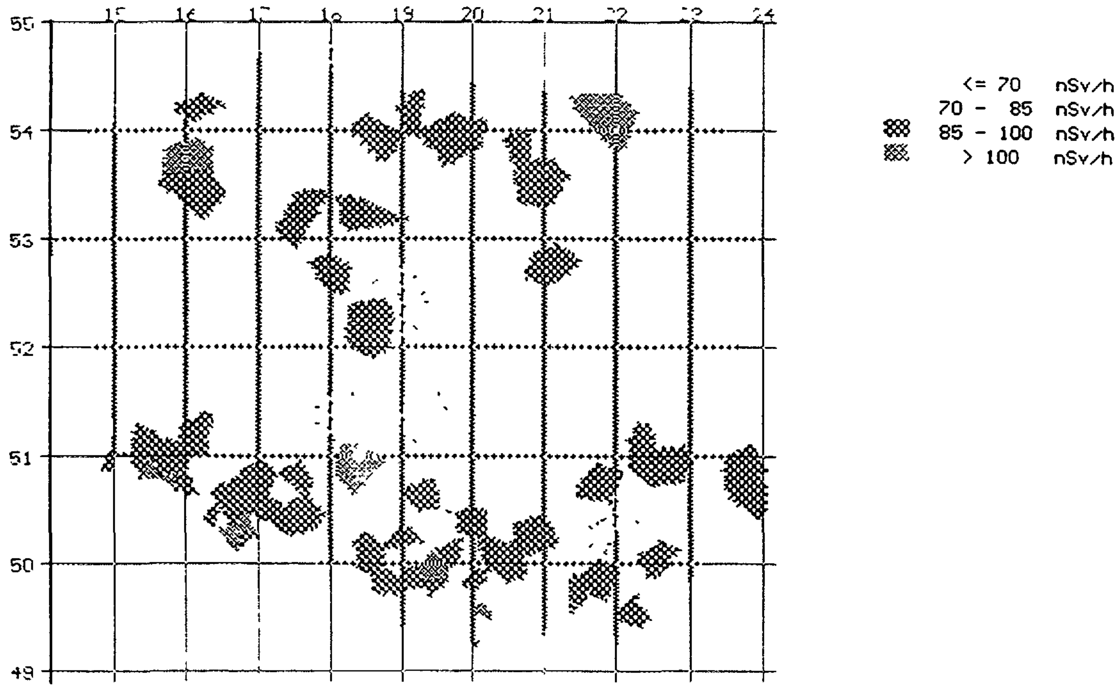

Fig. 2. Distribution of the average annual gamma dose rate in Poland in 1989.

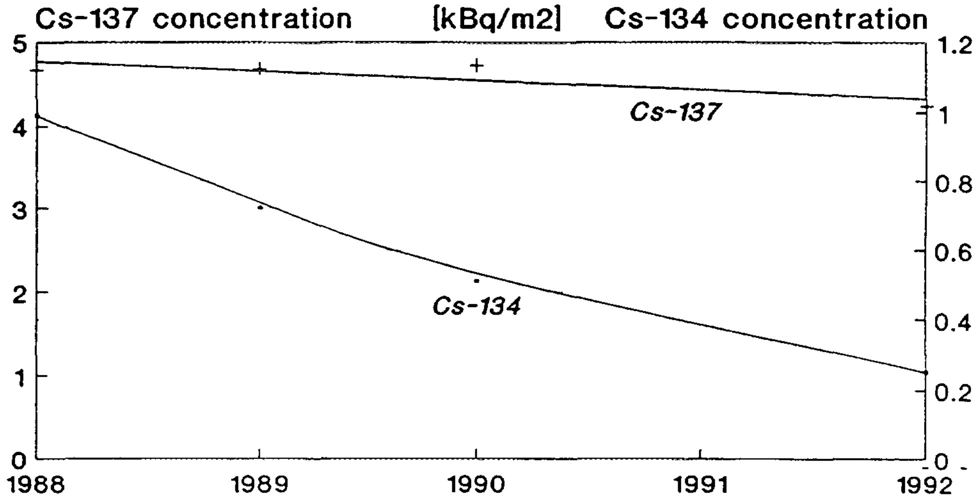

Fig. 3. Changes of ^{134}Cs and ^{137}Cs mean soil concentration in 1988 - 1992 in Poland.

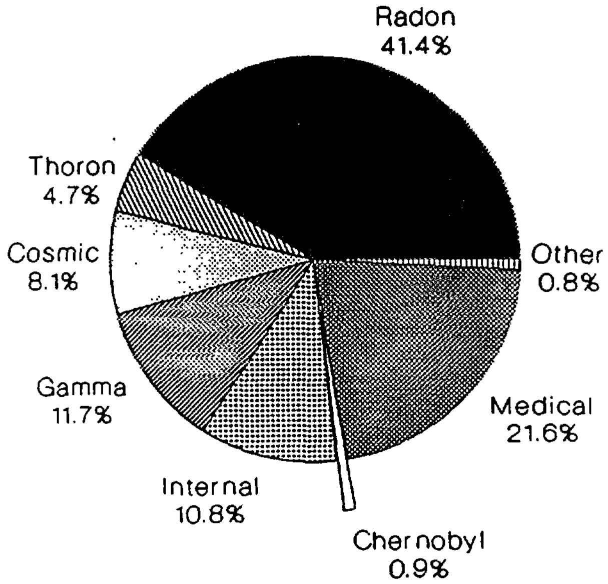

Fig. 4. Contribution of different radiation sources to the annual effective dose equivalent (3.6 mSv) to average individuals in Poland in 1991.

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CHARACTERISTIC FEATURE OF THE DEVELOPMENT OF THE RADIATION SITUATION IN BULGARIA FOLLOWING THE CHERNOBYL ACCIDENT

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ОДНА ХАРАКТЕРНАЯ ОСОБЕНОСТЬ В РАЗВИТИЕМ РАДИАЦИОННОЙ ОБСТАНОВКИ В БОЛГАРИИ ПОСЛЕ АВАРИИ В ЧЕРНОБИЛЬЕ

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ВВЕДЕНИЕ

Эта публикация представляет развитие радиационной обстановки в Болгарии после аварии в Чернобилье в нетрадиционном аспекте Повысеный радиационный риск для населения на год после события интерпретируется как функция неадекватной радиационно-защитной политики тогдашной администрации страны. Авторы не политизировают проблему, но десятилетная его давность все еще не преодолена в полно осторожность болгарской обществености к пережитого и ее недоверие к ответствеными инстигуциями

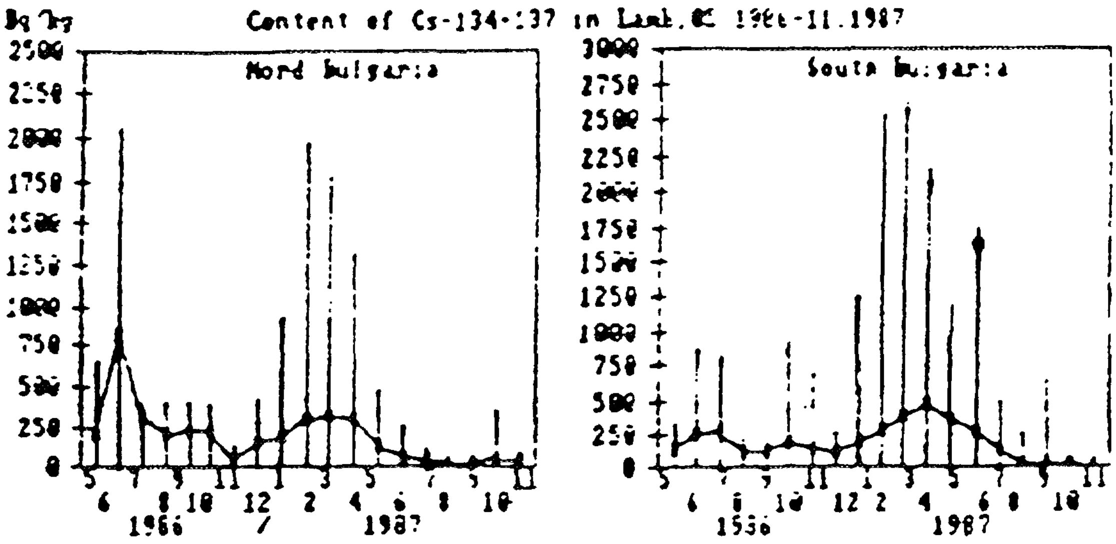
КОРОТКИЙ АНАЛИЗ ФАКТ В ХРОНОЛОГИИ СОБЫТИЯ

Ранный период развития радиационной обстановки в Болгарии после аварии определяется с интензитета трансграничного переноса радиоактивного загрязнителя. Но его тяжесть дефинируется с комплексными обстоятельствами особеноси в синоптике региона, совпаление с вегетационным периодом раститеньности и нактация продуктивными животнами

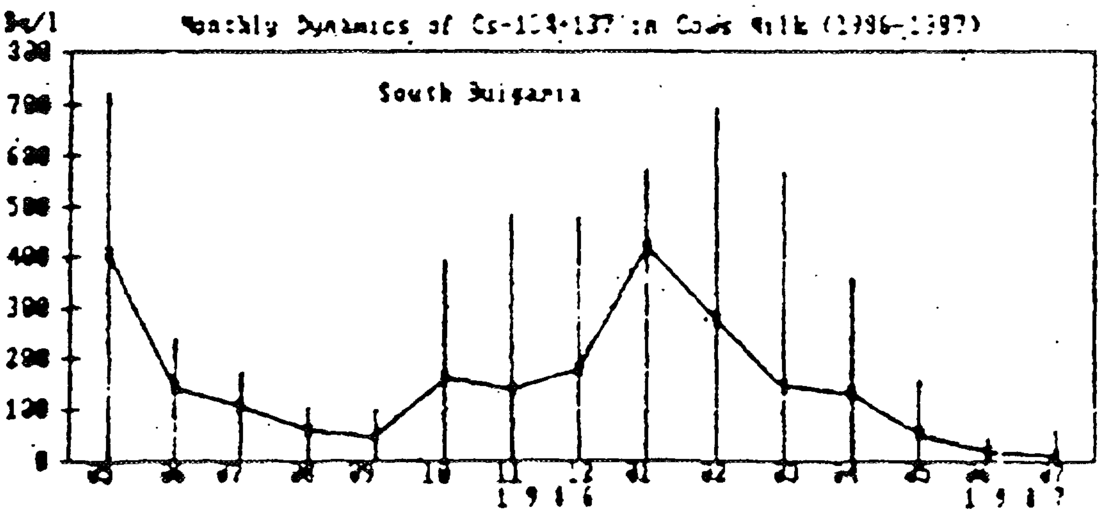
Это обословило высокую начальную контаминацию основных пищевых продуктах, которая быстро снизилось с 5 до 8 раз в следующих четыри месяца. Компетентные професиональные институции передставили властям долготрайную прогнозу для возможности возникания повторного контаминационного процесса если допустится выкормливание продуктивными животными зимного периода с загрязненным фуражных запасов из ранного послеаварийного периода. Рекомендованы были модели и методы для редуцирования загрязнения животынской продукции, системный контроль пищевых доставок для населения, как и допустимых в экономическом аспекте способы деконтаминации. Недооценивание рисковых эффектов события на здоровье нации, неумелое использование или сознательное неиспользование материально-технических возможностей государства и ее научного потенциала не позволили приложении этих рекомендовании. Предпочитание к конюнктурно-политических и коммерческо-экономических соображении перед радиационно-гигиенными принципами довели к следующим

РАДИОЭКОЛОГИЧНЫМ, РАДИОБИОЛОГИЧНЫМ И ЭКОНОМИЧЕСКИМ ПОСЛЕДСТВИЯМ :

1. Прогнозированный второй контаминационной процесс начался еще в октябр по ноябр 1986 г, а в периоде март-апрель 1987 г содержание цезиевых радионуклидов перевысило установленую аварийную норму с 600 Bq/kg для бараниного мяса с 35 до 45 % от иследоваемых доставок Южней Болгарии. Только 26-37 % с этих партид были ниже нормы для остальных видов мяса - 350 Bq/kg. Обще для страны со специфическую активность до 350 Bq/kg были 58 % из обследованных партид, с 350-600 Bq/kg - 20 %, а выше 600 Bq/kg - 22 %, достигающие активность до 7200 Bq/kg, 15-



Фиг.1 Динамика средномесячным максимальным, среднoарифметическим и минимальным стоимостей для содержания Cs-134 +Cs-137 в мясе маленьких рогатых скотов (май 1986-ноембр 1987)



Фиг.2 Динамика средномесячным максимальным, среднoарифметическим и минимальным стоимостей для содержания Cs-134 +Cs-137 в молоке коровь Южней Болгарии (май 1986-ноембр 1987)

50 % из молочных доставок были неподходящие для консумации при максимальными стоимостями цезиевым радионуклидом до 1200 Bq/kg [1](фиг.1 и 2)

2 В логической корелации с этим фактом является динамика инкорпорационного процесса в человеческим контингентом Южней Болгарии, у которых средне-

специфическая активность Cs-137 + Cs-134 за периода майя-июня 1987 г достигла 320 Bq/kg [2]. Эти стоимости являются аналогичными целотелесной активности городского населения Брянской области этого периода (342 Bq/kg). Они в унисоне с констатации United Nations Scientific Committee on the Effects of Atomic Radiation для самую высокую индуцированую эффективную эквивалентную дозу у взрослого населения Болгарии инкорпорированных цезиевых радионуклидов [3]. По коэффициент защиты болгарское население занимает одно из крайних мест среди затронутых стран

3. Экономические последствия созданной ситуации определяются уменшением количества молока для населения в 1987 г, недопускивание определенных партид мяса на внутренной рынке или выключивание с экспортной листе страны и с производственными затруднениями при натурального использования высоко-контаминированных животинских суровин Все это довело до конкретных финансовых потерии страны Но они являются несъизмеримыми с бесспорному факту, что одна активная профилактическая позиция властям сбережила бы болгарскому населению примерно 30 % с допольнительному лучевому нагружению вследствие катастрофы в Чернобилье [4].

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ASSESSMENT OF THE DYNAMICS OF THE RADIOACTIVITY CONTENTS IN SURFACE WATERS IN CONTAMINATED AREAS

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ОЦЕНКА ДИНАМИКИ РАДИАЦИОННОГО СОСТОЯНИЯ ПОВЕРХНОСТНЫХ ВОД В ЗАГРЯЗНЕННОЙ ЗОНЕ РЕСПУБЛИКИ БЕЛАРУСЬ

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In the connection with Chernobyl APS accident, since 1988 a network of sites was established for radioecological monitoring of surface water systems, mainly, small rivers on all Belarus territory.Small rivers are the principal way of radionuclides run off in liquid and solid discharges during rains and high-floods and their re-distribution in landscapes. The components of water systems radio-monitoring were water and water suspensions, area water-collection, bottom deposits and biota. In the paper the data are cited of radioecological studies of water systems components. Their analysis is done and some conclusions made which may be used for the development of radioecological prognosis and for taking environmental measures.

1. ВВЕДЕНИЕ

В границах Беларуси насчитывается более чем 10 тысяч озер и протекает более 20,8 тысяч рек общей длиной 90,6 тысяч километров. Главные реки - Днепр с Припятью водосбора Черного моря - дренируют 56 % территории Беларуси, а Нарев с Бугом, Неман, Западная Двина и Ловать, относящиеся к водосбору Балтийского моря - 44 %. Неман только начинается в республике, а Сож, Припять, Западная Двина и Днепр являются транзитными реками. Средний многогодовой сток рек Беларуси составляет 36,4 км^3 (без транзитного стока). 78 % суммарного годового стока рек республики приходится на Днепр, Сож, Припять и Неман [1]. Основные площади Территории Беларуси, загрязненные радионуклидами техногенного характера, приходятся на бассейны этих рек.

Преимущественно радиоактивное загрязнение после аварии на Чернобыльской АЭС сформировалось на западном, северо-западном и северо-восточном направлениях от станции, захватив бассейны Днепра, в особенности территории бассейна Припяти. Большая часть радионуклидов осела в 30-километровой зоне и на ближайших территориях, на водосборе и акваториях Днепра и Припяти, в бассейнах которых сосредоточены пахотные и мелиоративные земли, способствующие усилению данного процесса. Основным каналом выноса радионуклидов из площадей водосбора являются малые реки. Следует отметить, что на данных территориях плотность проживающего населения значительна. В связи с этим коллективная мощность дозы, поглощенная человеком от радиоактивного загрязнения, велика. Радиоактивность площадей водосбора привела к загрязнению поверхностных и подземных вод.

Водная среда играет особую роль при определении последствий аварии как для человека, так и для объектов флоры и фауны. Радиоактивные вещества поступают в водоемы не только в результате атмосферных выпадений и прямых сбросов, но и вследствие смыва с площадей водосбора. В настоящее время происходит процесс перераспределения радионуклидов по площадям водосбора, связанный с их перемещением с возвышенных участков в понижения местности, на застойные участки, болота и между компонентами водных экосистем.

В связи с этим возникла необходимость решения сложных и многообразных радиоэкологических проблем. К ним следует отнести установление закономерности перераспределения радионуклидов между компонентами ландшафта, изучение процессов поступления радионуклидов в биотическую среду и далее по пищевым цепочкам к человеку, прогнозирование судьбы радиоактивных веществ в экологических системах для разработки практических мероприятий по снижению или ликвидации неблагоприятных последствий радиоактивных загрязнений.

Наиболее важным в вышеуказанных исследованиях является изучение динамики поведения ^{137}Cs и ^{90}Sr как основных радионуклидов, вносящих максимальный вклад в радиоэкологическую ситуацию ландшафтов. Поэтому задача работы заключалась в определении динамики установления влияния мелиоративной сети, дренирующей загрязненные территории, на процессы миграции этих радионуклидов в водных системах.

В поверхностных водных системах наиболее сильными концентраторами радионуклидов являются растительные гидробионты, донные отложения и взвеси [2-4]. Попадающие в поверхностные водные системы радионуклиды включаются в биотический круговорот, характер которого определяется как гидрологическими параметрами водотоков и водоемов, так и уровнем загрязнения акваторий, видовым составом растений и ихсообществ, особенностями рельефа местности и типами почв прилегающих территорий [5].

2. ОБЪЕКТЫ ИССЛЕДОВАНИЙ

Объектами исследования были компоненты водных экосистем: поверхностная вода, взвеси в воде, донные отложения, водная биота и почвогрунты площадей водосбора. Радиоэкологические наблюдения проводили на реперных площадках, расположенных на малых реках Брагинка, Несвич и Словечна бассейна Припяти, а также Липа и Сенна бассейна Сожа с затоном у д.Веприн и водохранилищем у д.Малиновка.

Река Брагинка - левый приток Припяти , длиной 179 км и площадь водосбора 2778 км^2, полностью зарегулирована и делится на три самостоятельных объекта, по которым отводят воду в Днепр - Брагинка Верхняя, Средняя и Нижняя. Долина реки выражена слабо, пойма низкая, заболоченная шириной 0,5-1 км, русло по всей длине канализировано.

Река Несвич - правый приток р.Брагинка, длиной 37 км, площадь водосбора 489 км^2. Долина не выражена, пойма в среднем течении двухсторонняя, шириной 0,2-0,4 км. Русло на протяжении 24 км канализировано. Река течет в зоне отселения.

Река Словечна - правый приток Припяти длиной 158 км, площадь водосбора 3600 км^2, протекает по лесной заболоченной местности равнины Мозырского Полесья, частично канализирована (в границах республики длина 109 км, площадь водосбора 3000 км^2), имеет три притока. В нее впадает Свенчанский канал из реки Желонь, русло извилистое. Река в своем нижнем течении расположена в зоне отселения. Основные притоки - Батився, Чертень, Ясенец. Долина трапецевидная, в низовьи сливается с поймой Припяти. Ширина поймы - 0,7-1 км, на некоторых участках до 2,5 км. Пойма двухсторонняя, русло извилистое, местами канализировано.

Река Липа - приток р.Сож, длина 62 км, площадь водосбора 577 км^2. Наибольшие притоки - р.Глинка и Прудовка. Долина реки трапецевидная, шириной от 1 до 3,5 км. Склоны открытые, высотой 6-10 м. Пойма прерывистая, узкая и в нижнем течении двухсторонняя, от 0,5 до 3 км. Русло реки длиной 15,8 км, канализировано. В реку впадает сеть мелиоративных каналов.

Река Сенна - левый приток р.Сож, длина 59 км, площадь водосбора 543 км^2. Основные притоки - Сененка, Расамаха, Турья, Домашня, Ректа. Протекает в границах Оршанско-Могилевской равнины, долина трапецевидная, глубоко врезанная, ширина от 0,3 до 1 км. Пойма двухстороняя, в верховьи ширина 30-60 м, в нижнем течении - 300-500 м, местами открытая, луговая. Русло от истока канализировано, а в нижнем течении - сильно извилистое, шириной 5-19 м, у д.Пильня расширяется до 17 м. Берега умеренно крутые. В верховьи у д.Малиновка создано водохранилище. Река используется как водоприемник мелиоративных каналов.

Реки Брагинка, Несвич, Словечна дренируют Мозырско-Хойникско-Брагинский почвенный район, для которого характерны дерново-подзолистые почвы, развивающиеся на лесовидных суглинках (местами лесах).Рельеф этого района выражен Мозырско-Хойникской грядой, которая возвышается в отдельных местах до 50 м над окружающей местностью. В восточном направлении постепенно гряда понижается и в районе гг.Хойники и Брагин сливается с окружающим ее Гомельским Полесьем.

Территория района, по которому протекает р.Липа, имеет плоско-волнистый рельеф, местами осложненный невысокими сильноолаженными моренными грядами. Выравненность территории способствует задержанию талых вод и атмосферных осадков, что создает условия для развития процессов заболачивания почв. В Буда-Кошелевском районе 43,7% составляют переувлажненные в разной степени почвы. Преобладают дерново-подзолистые сильно и среднеоподзоленные, местами слабо-эродированные на легких водно-ледниковых, иногда лесовых суглинках, подстилаемых моренными суглинками, иногда песками. Суглинистые почвы занимают в районе 72%, супесчаные - 10%, песчаные - 3%, торфяники - 3%.

Для района, где протекает р.Сенна, характерен выравненный, волнистый рельеф со слабым расчленением. Он служит как бы переходом к Полесской низменности. Высота поверхности района при перемещении в южную сторону постепенно снижается на 20-30 м. Здесь преобладают дерново-подзолистые средне- и контактно-оподзоленные почвы на водно-ледниковых, реже моренных супесях, подстилаемых в пределах почвенного профиля моренными суглинками или песками. Наличие выравненности территории и наличие водоупорной породы создают условия для заболачивания земель.

3. МАТЕРИАЛЫ И МЕТОДИКА ИССЛЕДОВАНИЙ

Отбор проб почвогрунтов осуществляли металлическими пробоотборниками диаметром 40 и высотой 250 мм. Пробы воды объемом 40-50 литров отбирали в пластмассовые емкости, а затем фильтровали через бумажные фильтры "белая" и "синяя" лента. Донные отложения для анализа извлекали пробоотборником поршневого типа. Образцы почвогрунтов, донных отложений, гидробионтов, фильтров со взвесями исследовали в лабораторных условиях методами гамма-спектрометрии, радиометрии, радиохимического, элементного и химического анализов с применением следующих приборов: дозиметра ДРГ-01Т, радиометра-дозиметра МКС-01Р, бета-радиометра РКБ-4-1еМ, многоканального полупроводникового гамма-спектрометра на основе Ge (Li) детектора ДГДК-100В и амплитудного анализатора LP-4900, атомно-абсорбционного спектрометра ASS-30. Пробы взвесей, донных отложений, водных растений, моллюсков и рыб высушивали до постоянной воздушно-сухой массы. Биоту озоляли в муфельной печи при температуре 450°С. Гамма-спектрометрический анализ проб почво грунтов, донных отложений, гидробионтов проводили на сухих образцах. ^{90}Sr концентрировали из проб в виде карбонатов и определяли по дочернему продукту - ^{90}Y.Удельная активность взвесей, донных отложений, водной растительности, моллюсков и рыб приводится в Бк/кг воздушно-сухой массы.

Анализу подлежали растения, наиболее характерные для водных экосистем Беларуси. Из воздушно-водной экологической группы наиболее часто отбирали пробы аира пахучего *(Acorus calamus L.)*, тростника общего *(Phragmites communis Trin.)*, рогоза широколистного *(Typha latifolia L.)*; из группы гидато- и аэрогидатофитов анализировали пробы видов - ряски маленькой *(Lemna minor L.)*, элодеи канадской *(Elodea canadensis Rich.)*, многокоренника *(Spirodela polyrriza L.)*, кубышки желтой *(Nuphar luteum Sm.)*, роголистника погруженного *(Ceratophylum demersum L.)*, рдеста плавающего *(Potamogeton natans L.)*; из группы гигрофитов - осока острая *(Carex acuta L.)*, ежеголовник простой *(Sparganium simplex Huds.)*, камыш лесной *(Scirpus silvaticus L.)*, ситник развесистый *(Juncus effusus L.)*.

Гидрофауна представлена моллюсками: прудовик болотный *(Limnaea stagnalis)*, живородка болотная *(Viviparus contectus)*, катушка роговая *(Planorbarius corneus)*, беззубка обыкновенная *(Anadonta cygnaea)*, перловица обыкновенная *(Unio pictorum)*, и рыбами: плотва *(Rutilus rutilus L.)*, карась *(Carasius carassius L.)*, щука *(Esox lucius L.)*, окунь *(Perca fluviatilus L.)*, ерш *(Gymnocephalus cernua)*.

4. РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ И ИХ ОБСУЖДЕНИЕ

В период наблюдений радиоэкологическая ситуация характеризовалась уменьшением плотностей загрязнения площадей водосбора со временем, что обусловлено как распадом сравнительно короткоживущих радионуклидов ^{134}Cs, ^{106}Ru, ^{144}Ce, так и смывом и перемещением ^{137}Cs и ^{90}Sr как по поверхностям площадей водосбора, так и в глубину грунта. Диаграммы динамики содержания ^{137}Cs и ^{90}Sr в поверхностной фильтрованной воде, почвогрунтах площадей водосбора, в донных отложениях и гидробионтах характерных реперных площадок представлены на рис.1 и 2.

Удельная активность фильтрованных проб поверхностных вод на всех полигонах не превышала, как правило, Республиканские контрольные уровни для питьевой воды - 18,5 Бк/л по ^{137}Cs. Удельное содержание ^{90}Sr в фильтрованной воде рек, дренирующих наиболее загрязненные районы Гомельской области (Брагинка, Несвич) намного превышало контрольные уровни - 0,37 Бк/л. В то же время в воде р.Словечна, протекающей по загрязненной зоне, содержание ^{90}Sr в воде только в отдельные годы (1994,1995) превышало контрольные уровни. Такое явление, когда содержания ^{90}Sr в воде рек, протекающих в практически одинаково загрязненной зоне, значительно отличаются от пункта к пункту, можно объяснить неординарностью гидрологического режима реки. Так, река Брагинка в устье Брагинки Нижней имеет среднегодовой расход воды - 3 м^3/с. Река Несвич - 1,6 м^3/с при среднем наклоне водной поверхности 0,2‰. Река Словечна имеет среднегодовой расход воды в устье 13,7 м^3/с, средний наклон водной поверхности - 1,1‰.Отсюда следует, что скорость течения воды в р.Словечна немного превышает скорость течения воды в рр.Брагинка и Несвич, а расход воды приблизительно в 10 раз выше. Таким образом, имеет место ускоренный вынос поступивших в воду радионуклидов за счет большого наклона водной поверхности. Процесс поступления радионуклидов ввиду идентичности плотности загрязнения площадей водосбора примерно одинаков для рр.Брагинка, Несвич и Словечна.

Удельная активность фильтрованных проб поверхностных вод на всех полигонах рр.Сенна и Липа, как правило, не превышала Республиканские контрольные уровни для питьевой воды по ^{137}Cs, и ^{90}Sr. В отдельных случаях содержание ^{90}Sr превышало содержание ^{137}Cs в фильтрованной воде, что подтверждает более высокую подвижность первого.

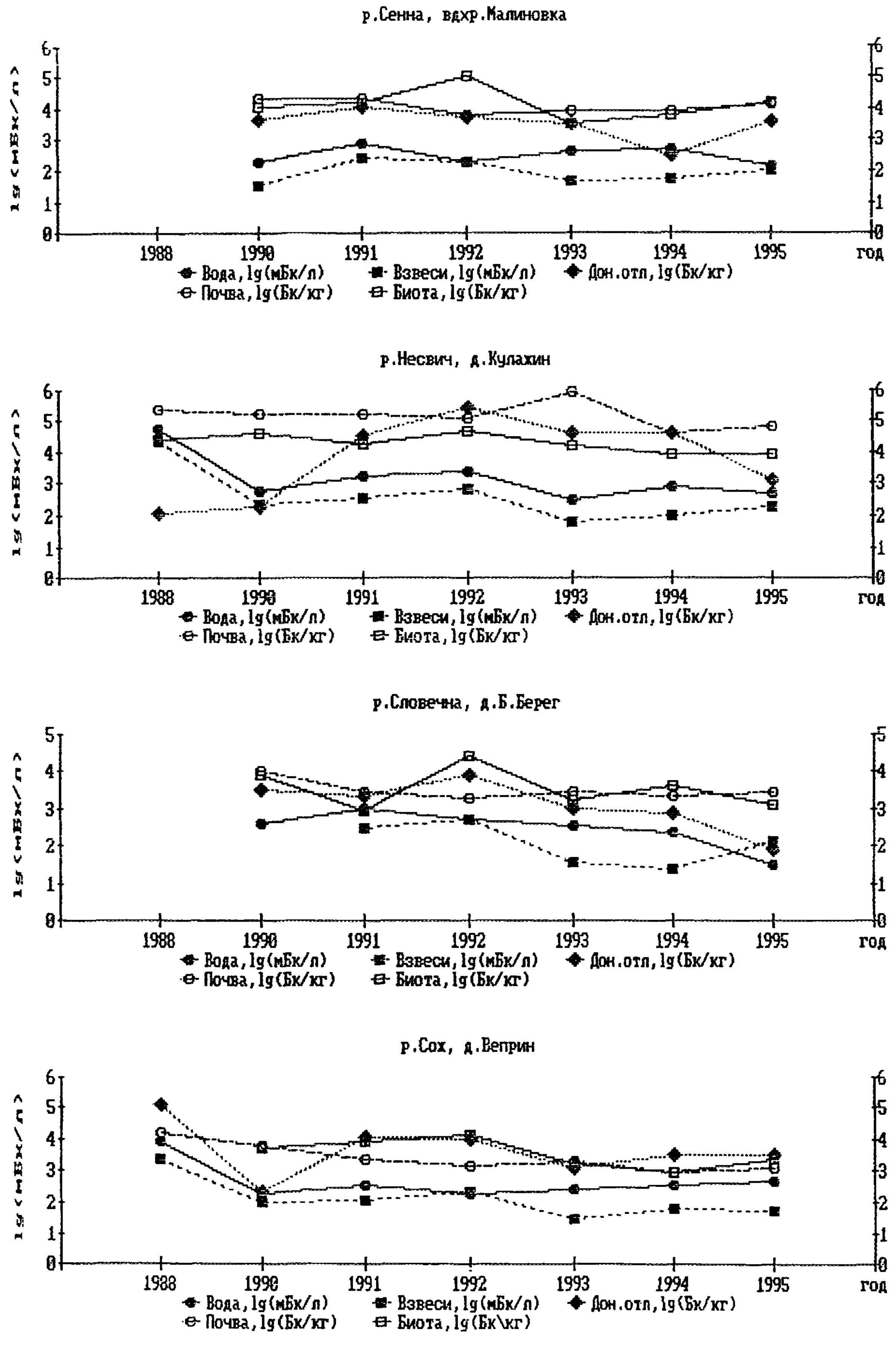

Рис. 1. Динамика содержания Cs-137 в компонентах водных систем.

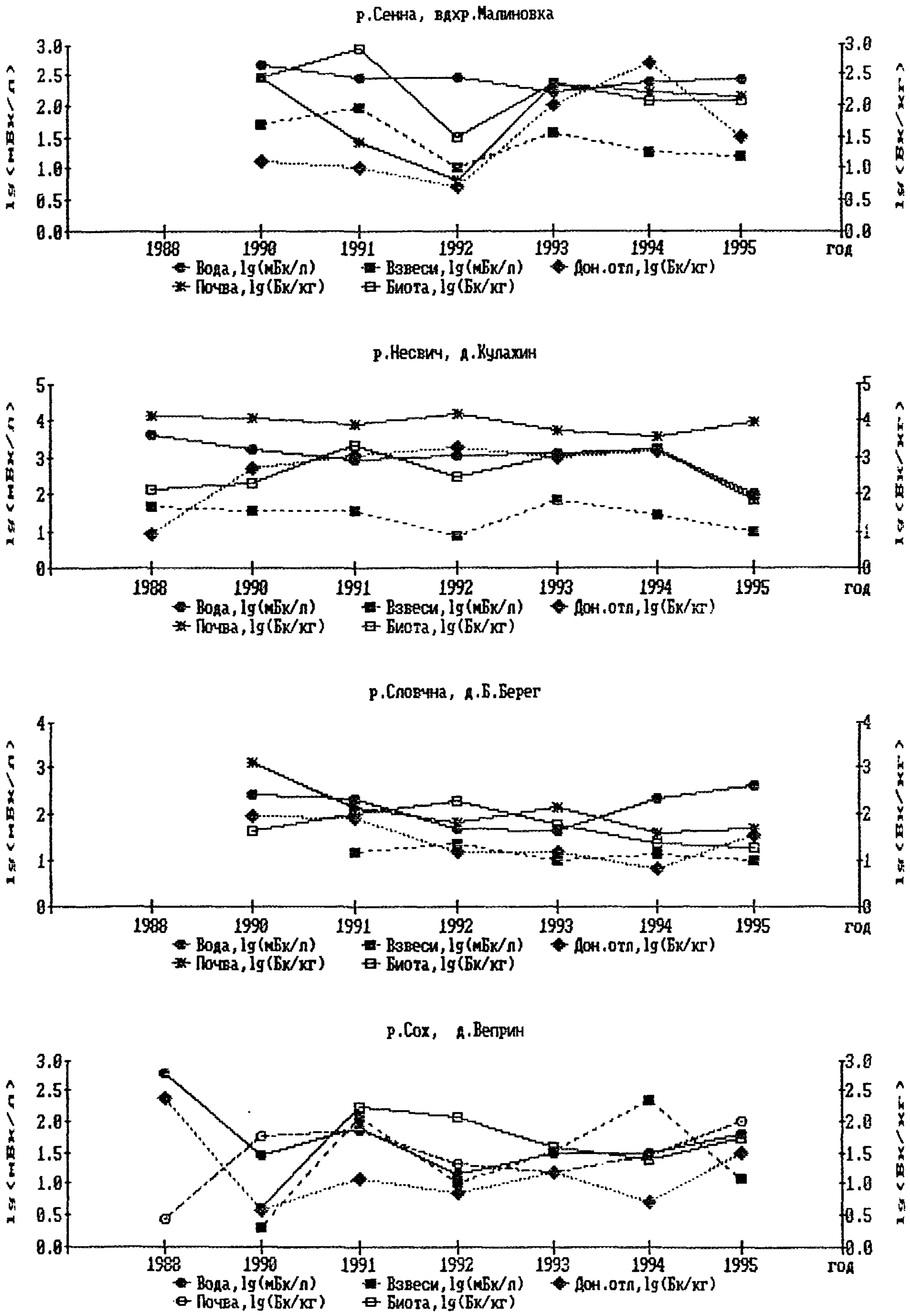

Рис. 2. Динамика содержания Sr-90 в компонентах водных систем.

Экспериментальный материал за период наблюдения свидетельствует, что изменение концентраций радиоактивных веществ в поверхностных водах малых рек не было монотонным, а их максимальные значения регистрировались в разные времена года. При этом максимальные значения концентрации ^{137}Cs и ^{90}Sr в основном приходятся на позднеосенний и весенний периоды. Однако в периоды большого подъема воды возможно разбавление речных вод нерадиоактивной водой, что приводит к уменьшению содержания радионуклидов, а в летний, при малых выпадениях, дождей концентрация радионуклидов в воде, может превосходить концентрацию в осенне-весенний периоды. Следует отметить, что на всех контролируемых полигонах, находящихся в зоне максимального загрязнения , концентрации ^{90}Sr, особенно в осенне-весенний период, часто превосходили концентрации ^{137}Cs в поверхностной воде в период паводков и половодий, что, вероятно, связано с особенностями форм существования этих разных по растворимости и миграционным свойствам радионуклидов. Кроме того, в позднеосенний период происходит отмирание водной растительности и освобождение из органики в первую очередь соединений ^{90}Sr.

Отношение содержаний ^{137}Cs к ^{90}Sr в поверхностных водах большинства полигонов наблюдения непостоянно и, как правило, больше 1. В воде рр.Липа и Сенна, дренирующих загрязненные районы Могилевсой области, оно было в большинстве случаев больше 1, а в реках, протекающих по наиболее загрязненным районам Гомельской области, составляло величину меньше 1. В почвогрунтах площадей водосбора отношение содержаний ^{137}Cs к ^{90}Sr имеет значительно большие величины, что, по-видимому, обусловлено повышением миграционной способности вновь образованных форм соединений ^{90}Sr и их количественного состава по сравнению с ранее существовавшим [6].

В составе речного стока большую роль играет перенос радионуклидов на твердых взвесях. Обычно считается, что он достигает величин от 10 до 30-40% общей активности воды. В период паводков и половодий синхронно с ростом общей активности возрастает и доля активности ^{137}Cs (до 70-80%), связанной с твердыми взвесями, которая чаще всего относится к фракции 0,2 мкм (глинистые минералы). Однако известны случаи, когда большая часть активности (60-70%) тяготеет к более крупным фракциям. Количество ^{137}Cs и ^{90}Sr на взвесях в значительной степени зависит от сезона отбора проб воды, гидрологического и видового режима водного объекта, взмученности воды и количества органики и глинистых частиц во взвешенном состоянии.

Полученные данные свидетельствуют, что уровень загрязнения ^{137}Cs и ^{90}Sr донных отложений на 2-4 порядка выше уровня загрязнения воды. Поскольку загрязненные донные отложения постоянно мигрируют по течению водотоков и перемешиваются с влекомыми наносами и разбавляются нерадиоактивными наносами, установление точных величин накопления радионуклидов в донных отложениях водотоков затруднено.

Анализ данных показывает, что наибольший вклад в суммарную активность донных отложений обычно вносит ^{137}Cs (более 80%). Однако такая пропорция наблюдается не на всех площадках наблюдения рек. Ситуация зависит от их места расположения. Имеются такие площадки наблюдения, где вклад ^{137}Cs в суммарную активность ниже 50%.

Для случая, когда содержание цезия-137 превосходит содержание стронция-90 в воде проточных водоемов просматривается ряд: донные илистые отложения затонов > береговые наилки > русловые крупно- и средне-зернистые отложения. Такая закономерность объяснима с точки зрения гидрологического режима водотоков и их заростанием водной растительностью. Как известно [4], в проточных водоемах, особенно с быстрым течением воды, основная масса водной растительности расположена у берегов. Следовательно, именно здесь отмершая и разложившаяся растительность попадает на дно и откладывается в местах, где скорости движения воды наименьшие или в тех местах, куда слабым потоком воды уносится отмершая органика. Таким местом в реке и являются затоны и береговая кромка воды.

Анализ результатов радиоэкологического состояния водной биоты показал, что для водохранилища Малиновка (образовано запруживанием р.Сенна) Чериковского р-на Могилевской области максимальные значения удельных активностей ^{137}Cs отмечены в июле 1991 г. для проб элодеи канадской - 377 000 и омежника водного - 241 000 Бк.кг воздушно-сухой массы. Такого же порядка величина была установлена и в апреле 1992 г. (114 700 Бк/кг) для пробы детрита (в местах массового произрастания в летний период элодеи и аира). В последующие годы значения ^{137}Cs стабилизировались на уровне n x 10^3 - n x 10^4 Бк/кг воздушно-сухой массы. Максимум содержания ^{90}Sr в пробах макрофитов за весь период наблюдений был отмечен у элодеи канадской , отобранной в мае 1990 г. - 721 Бк/кг. Вцелом, значения ^{90}Sr для проб водной растительности находятся в диапазоне величин 14 (проба частухи подорожниковой водной, июнь 1995 г.) - 721 Бк/кг. Для проб моллюсков, в основном брюхоногих, интервал удельных активностей ^{90}Sr следующий: 62 (июль 1994 г.) - 357 (июль 1991 г.) Бк/кг, т.е. в более ранний период отбора этот показатель был выше.

Для затона р.Сож у д.Веприн того же района (водоем также лентического типа) удельная активность проб водной растительности по ^{137}Cs не превышала значения 20 700 Бк/кг, отмеченного в пробе гигрофита осоки острой в мае 1990 г. Среди типичных гидрофитов максимальные значения содержаний ^{137}Cs отмечены в пробах ряски маленькой и многокоренника - 11 100 Бк/кг и элодеи - 11 000 Бк/кг, отобранных в июле 1991 г. и в пробе детрита за апрель 1992 г. - 12 900 Бк/кг. В основном, уровень активностей ^{137}Cs в пробах водной растительности находился в интервале величин n x 10^2 - n x 10^3 Бк/кг, где n=1-9. В отношении ^{90}Sr среди проб макрофитов максимальное значение отмечено в пробе элодеи канадской - 402 Бк/кг (май 1993 г). Диапазон величин активностей биоты по ^{90}Sr для этого полигона в период 1990-1995гг. колебался от 11 Бк/кг(корневища аира, май 1990 г.) до уже названной величины - 402 Бк/кг. Пробы брюхоногих моллюсков (в основном живородка болотная) в отношении ^{90}Sr в разные годы проявляли различную радиоактивность - от 49 Бк/кг (июль 1994 г) до 146 Бк/кг в июле 1991 г., т.е. в более ранние сроки отбора их активность была более значимой. В мае 1993 г. анализировали ихтиофауну (особи 2-х 3-х лет). В отношении стронция-90 среди трех видов (окунь речной, щука, плотва) максимальное значение отмечено для окуня - 270 Бк/кг воздушно-сухой массы.

Для р.Несвич среди 2-х реперных площадок наиболее высокие удельные активности биопроб обнаружены у д.Кулажин. Так, по цезию-137 средние значения в период 1988-94 гг. находились на уровне n x 10^4 Бк/кг, и лишь в период 1994-95 гг. они уменьшились до n x 10^3 Бк/кг. В отношении ^{90}Sr интервал активностей биоты находится в пределах n x 10^1 - n x 10^3 Бк/кг.

5. ЗАКЛЮЧЕНИЕ

Изучение содержания радионуклидов Чернобыльского происхождения в основных составляющих ландшафта бассейнов малых рек (поймах, мелиоративных системах и водохранилищах) показало, что на загрязненных территориях водосборов происходит их горизонтальная миграция в воду и в донные отложения рек, мелиорационных каналов и водохранилищ, в растительную компоненту водных биоценозов и далее по трофическим цепям. Горизонтальная миграция сопровождается перемещением радиоактивного загрязнения из почвы верхних террас речных долин, приводя к формированию вторичных ареалов загрязнения на понижениях площадей водосборов.

Основным фактором, способствующим миграции радионуклидов, является водный поток по поверхности почвы. Процесс, безусловно, зависит от химического и элементного состава вод потока, физико-химических свойств радионуклидов, гидрологических условий, типа почв водосбора и многих других параметров.

На затапливаемые во время паводков и половодий поймы рек поступает с поверхностными водами в виде наилков и растворов дополнительное количество радионуклидов с вышележащих площадей водосборов. Они также поступают в результате процессов эрозии берегов каналов, рек и других водных систем.

Обобщение экспериментальных данных показало, что распределение удельных активностей ^{137}Cs и ^{90}Sr между компонентами водных систем можно расположить в следующей последовательности: водная растительность > моллюски, рыба > донные отложения > почвогрунты > вода.

Исследования подтвердили возросшую миграционную способность ^{90}Sr в связи с увеличением количества его водорастворимых и обменных форм.

Активность ^{137}Cs и ^{90}Sr в донных отложениях, как правило, максимальна в позднеосенний и ранневесенний периоды, а водной растительности - в летний, т.е. в пик вегетационных процессов.

В заключение следует отметить, что с точки зрения радиационной опасности водных систем доминирующая роль принадлежит гидробионтам и донным отложениям, на что необходимо обращать внимание в дальнейших научных исследованиях.

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RADIOBIOLOGICAL PROBLEMS CONCERNING GRAZING ANIMALS FOLLOWING THE CHERNOBYL ACCIDENT

XA9745878

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1. INTRODUCTION

Chernobyl accident took place on April 26 1986, which was the beginning of the grazing season, when there was not enough fodder on the farms and the cattle was grazed on the open territory. Therefore grazing animal-breeding was the most radioactively affected branch. The consumption of contaminated fodder and surface contamination with radioactive precipitation caused the accumulation of considerable ingested doses in the organisms of animals (up to 1 Gy).

Radioactive damage caused to the thyroid by the selective accumulation of radioiodine (mainly ^{131}I) is of particular attention. Cumulative doses of thyroid irradiation in mammals were much higher than for the other organs. Thus, in cows during their grazing on the contaminated pastures outside 30-km zone the ratio of ingested doses of the thyroid and whole body was 130:1 and more, therefore, radiation effects could have a certain negative effect, concerning the agricultural animals in the zone of accidental release influence. Accumulated ingested doses in the thyroid of cows on the contaminated territory in a number of cases caused the complete destruction of the thyroid (doses above 600 Gy), which provided the loss of milk productivity and reproductive qualities of the animals. Lower doses caused the functional disturbances, which in most cases have been levelled during the years after the accident.

2. METHODS

The research was carried out in various zones of radioactive contamination on the territory of Ukraine. Cattle has been the main object of investigation.

For the assessment of biological effects experimental groups of animals were selected, ingested doses were calculated, parameters of clinical status of animals, as well as indices of haematological, biochemical, endocrine, immune status of organism were investigated. Pathomorphological study of organs and tissues of animals, affected by Chernobyl radioactive fallout, was carried out. Productive and reproductive qualities of these animals were estimated.

In order to study the possibility of obtaining animal products with minimum content of radiocaesium, various sorbents were investigated. The preparations of ferrocianides groups have displayed itself as the most effective. With the help of Norwegian specialists various forms of these sorbents were tested, the efficiency observed amounted from 4 to 10 times.

Various technological and organisational measures, which provided the production with minimum content of radionuclides in final products, were analysed.

3. RESULTS

The priority of basic trends of work varied with the time after the accident.

In the acute period main attention was attributed to the degree of affection of animals, caused by Chernobyl radioactive fallout, and to the identification of the possibility of their use for production. Doses of animals varied from several tens rad for the whole organism to tens thousands rad for the thyroid gland at the rate of radioactive iodine (Table I)

Table I

Formation of ingested dose in the organism of cattle beyond the 30-km zone*

Years	1986	1987	1988	1989	1990	1991
Doses, cGy	34	14	8	6	3	2

* Thyroid dose was 4 000 cGy

Despite the fact, that the affection of the thyroid did not threaten with the death of animals, 15 thousand heads were slaughtered in the first months after the accident because of the fear of development of X-ray disease. This was the reason of a number of problems with contamination of the places of slaughter, storage and utilisation of the contaminated material. In 1986-1987 more than 40 thousand heads of cattle were slaughtered, in the meat of which the content of radionuclides exceeded permissible levels.

On the background of non-balanced nutritional content of the diet and endemic character of Polessye zone , which is depleted in a range of biogenic microelements, the general state of animals on separate farms of Ukrainian contaminated territory was unsatisfactory, therefore the problem of reducing the amount of animals appeared.

The accident considerably affected the sheep-breeding of Ukraine. As a result of surface contamination of wool, this valuable product could not be used for processing.

The main reasons, which caused the losses in animal-breeding in the immediate period after the accident:

- the refusal of the possibility of serious accidents in nuclear industry, which practically excluded even hypothetical preventive analysis of such events
- absence of information on the scales of the accident, which caused the loss of time for decision-making and radioprotective measures in animal-breeding
- unreadiness of administrative organs and practical workers for urgent measures for preventing the losses after the accident
- underestimation of psychological factor in agricultural production
- not using of available recommendations and instructions on agricultural production in the conditions of terrestrial radioactive contamination

Despite very hard consequences of ChNPP accident, the basic paradigm of radioecology was confirmed - the territory, where the signs of radioactive damage of living organisms in the contaminated environment are found, is much less in size than the area, where the concentration of radionuclides in natural objects and, first of all, in agricultural products, consumed by the population, exceeds maximum permissible levels, and where the uncontrolled residence of people is impossible.

Therefore the main radiobiological problems in the postaccidental period are connected to the production of animal products, corresponding to the permissible levels.

Dairy cattle-breeding is the most critical branch in the conditions of farmlands contamination with radionuclides. When lactating cows are transferred to contaminated feeds both in stalls and on the pastures, the significant increase if caesium-137 concentrations is observed in one day, and in 5-6 days it increases by one order of magnitude. The amount of such milk in the most contaminated Zhitomir region in 1987-1989 was 13-14% in grazing period, while in stalls - 7-8%, in Rovno, Kiev, Chernigov regions - 1-3% and 0.1-0.6% respectively. The main factors of improving the situation in milk production were the exclusion of farmlands with contamination density above 555 kBq/m^2 , application of the complex of agromeliorative measures, production of fodder, differentiated by contamination levels, and in private sector - allocation of the improved pastures for the population and forbidding of grazing on uncultivated pastures. As a result, the milk with contamination exceeding permissible levels was not produced since 1992 (Table II) .

Table II

Amount of milk sent to the processing factories from collective farms, which exceeded the permissible level 370 Bq/L, thousand tons

YEARS							
1988	1989	1990	1991	1992	1993	1994	1995
78	61	62	1	0	0	0	0

Due to high contamination of animals, which were sent to processing factories, the technology of 3-stage final fattening of cattle with "clean" fodder had been developed and implemented in 1987. Besides, on meat-processing enterprises the techniques of in-vivo measurement of radionuclides concentration in the muscle tissue of animals was used. This techniques was developed by UIAR [1]. It allowed to avoid premature slaughter of contaminated cattle without preliminary clean-feeding. As a result, despite 2-fold lowering of permissible levels, the amount of contaminated meat, sent to processing enterprises, reduced and at present this problem does not exist (Table III).

Table III

Amount of meat sent to the processing factories from collective farms, which exceeded the permissible levels*, thousand tons

YEARS									
1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
6410	1280	168	64	17	35.4	5.2	5.2	2	2

* 1986-1987 - 3700 Bq/kg, 1988-1990 - 2960 Bq/kg, since 1991 - 740 Bq/kg

The production of "clean" fodder on natural hay-mowing plots and pastures is an important problem in the organisation of animals feeding, as on these lands. in contrast to the fields, ploughed after the accident, the migration of radionuclides, first of all, of ^{137}Cs, has a number of peculiarities.

First of all. greater part of radiocaesium on natural meadows (70-98%) is located in the turf - upper horizon of soil profile enriched with non-mineralised part of plant residues.

Second, the presence of turf with the concentration of ^{137}Cs is 14 times higher than in plants often causes increased (as compared to rood uptake) transfer of radionuclides to grass stand. The third peculiarity of radionuclides migration on meadows is determined by the regular flooding of most of these lands. This causes not only intensive transport of radionuclides in the soil profile, but also the enhanced accumulation of ^{137}Cs in meadow plants. Thus, ^{137}Cs transfer factors (TF) from soil to plants on wet meadows is 3-8 times higher than on dry meadows.

The content of ^{137}Cs in fodder, produced in natural conditions, will depend greatly on the specific composition of vegetation on meadows. For instance, on peaty meadow the specific peculiarities of plants determine the 10 times variations in ^{137}Cs accumulation [2].

For the reduction of radiocaesium transfer from diet to animal organism and animal products, a large number of preparations, which make possible the decrease of radiocaesium transfer to milk and to muscle tissue of animals, has been tested. The most effective, in respect of binding capacities, were the preparations from the group of zeolites, which provide 3-fold reduction of radiocaesium transfer from diet to milk, ferrocianides - 4-6 times reduction, microelement additives - 1.5-2 times (Table IV). The institute has purchased and distributed ferrocine in the most contaminated districts of Zhitomir and Rovno regions. It was observed that in industrial conditions the efficiency of sorbents application is lower than in experimental conditions.

Table IV

Efficiency of ferrocine and fodder additives on the basis of zeolites

Fodder additives	Decrease of ^{137}Cs concentration, times	
	Milk	Meat
Zeolites		
Humolite (clinoptilolyte):		
Animals in stalls	1.2 - 4	1.5 - 2.9
Animals on the pasture	1.5 - 3	-
Ferrocines:		
Salt-licks	2 - 5	-
Powder, 3-6 g/day	4 - 5	1.7 - 2.9
In the form of boli	3 - 4	-

The experience showed that even on one farm the final fattening of animals for obtaining clean products can be organised (Table V).

Table V

The variability of animals' diet contamination with ^{137}Cs within one collective farm and respective contamination of animal products

Farms	Intake with diet, kBq/day	Concentration in meat, Bq/kg	Concentration in milk, Bq/L
Col.farm Gorky			
Farm 1	0.4	16	4
Farm 2	21.5	860	210
Farm 3	35.5	1400	350
Col.farm Kirov			
Farm 1	1.0	38	10
Farm 2	2.1	83	21
Farm 3	3.1	120	31
Col.farm Vatutin			
Farm1	0.2	9	2
Farm 2	29.6	1200	300
Col.farm Schors			
Farm 1	1.8	72	18
Farm 2	5.2	210	52

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RADIOACTIVITY IN THE ROMANIAN BLACK SEA SECTOR ONE DECADE AFTER CHERNOBYL

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1 INTRODUCTION

Radioactivity monitoring in the marine environment was imposed by the increasing development of nuclear energetics and its world-wide use in many different activities [1]

Both natural and artificial radioactivity play an important role in marine ecology and human health, in this respect three major facts continue to prevail in Romania the fallout, the presence of the Danube river, and the future nuclear energy production by using of five CANDU reactors under construction at Cernavoda

Spatial and temporal monitoring of marine radioactivity along the Romanian Black Sea shore has been systematically perfomed by the Romanian Marine Research Institute (RMRI), in close co-operation with the Research Laboratory of Environmental Radioactivity (RLER) belonging to the Institute of Meteorology and Hydrology (until 1990) and to the Research Institute for Environmental Engineering (REIE) afterwards, since 1991

2 MATERIAL AND METHODS

Marine emerged and submerged sediments, coastal and offshore sea water, macroalgae, invertebrates and fish off the Danube mouths and/or along the coast have been monitored for natural and artificial radioactivity by means of alpha and beta gross measurements and gamma spectrometry

Materials and methods used for these continuous investigations have been described in previous publications [1, 2, 3, 4, 5]

Concentrations of various radionuclides in abiotic and biotic samples, environmental distribution coefficients (Kds) and concentration factors (CFs), as well as experimentally-derived CFs in marine biota as radioecological bioindicators have been assessed and stored for a national data base and for international uses

3 RESULTS

The alpha gross radioactivity level was always below the lower detection limit (LDL) for all samples excepting the green seaweed *Bryopsis plumosa*

The beta level was below LDL for sea water (salt), beach sediment (sand) and molluscs (shell) The averages for other samples were as follows 883 Bq kg^{-1} sediment (dry) off the Danube mouths, 152 Bq kg^{-1} fresh weight (f w) algae, 84 Bq kg^{-1} f w molluscs (soft part), 118 Bq kg^{-1} f w fish (comparable to 113 Bq kg^{-1} f w for fish originating in the FAO 34 (Mauritania) and FAO 47 (Namibia) zones of the Atlantic Ocean Again, *B plumosa* is an exception with values of 10 Bq kg^{-1} f w [6]

The gamma spectrometrycal analyses have been performed at RLER until 1992 and at RMRI ever since Low background, high resolution equipment has been used [7] Data quality control was ensured by taking part in international intercomparison runs organized by the IAEA (SD-A-1, IAEA-300, IAEA-306, IAEA-307, IAEA-315)

Since the last atmospheric nuclear test in the northern hemisphere (1980), during 1982-1984 fission radionuclide concentrations continuously decreased in the environment, including the Black Sea, until they were below detection limits This trend continued till 1985, when the lowest levels of radioactive pollution were registered in Romania No radionuclides originating from the releases of nuclear facilities were found during this time [3]

Before the major nuclear accident at Chernobyl, Ukraine, on April 26, 1986, the gamma activity of the samples was given mainly by the natural gamma emitters (K-40 and those in the U-Ra and Th series) Among the artificial gamma emitting radionuclides originating in the previous nuclear atmospheric tests, Cs-137 was the most significant The evolution of its concentration, showing a decrease towards detection limits in 1985 - early 1986, was marked by the mentioned accident

Gamma radioactivity monitoring along the Romanian marine coast in 1986 indicated an evident increase of radionuclide concentrations, as compared with the period 1983-1985, directly related to the Chernobyl accident

After the Chernobyl accident, interest in radioecological research of the Black Sea increased in Romania, as it did in a number of other countries [8], also other fission as well as activation products appeared in the marine environmental samples, such as Zr-95/Nb-95, Ru-103, Ru-106, Ag-110m, Sb-125, I-131, Cs-134, Ba-140/La-140, Ce-141, Ce-144

In the marine environment K-40 continued to prevail permanently in all components Ac-228 and Ra-226 were also determinated as indicators for the uranium-radium and thorium series Co-60, Ru-106, Cs-137 and Ce-144 were constantly analyzed since 1983, and Ag-110m and Cs-134 starting with May, 1986

In the predanubian area the isotopic ratios Ru-106/Ru-103 and Cs-137/Cs-134, as well as distribution coefficients (Kds) for submerged sediment and sea water from 10 and 20 m depth were estimated (Table I)

The isotopic ratio values of Cs-137/Cs-134 in sediments and sea water demonstrated that the Chernobyl accident was a source of radioactive contamination along the Romanian shore

Given their importance, special attention was paid to Cs-134 and Cs-137, for which international organizations established maximum permissible limits for food products following the Chernobyl accident Romanian studies thus particularly focused on computing the concentration of Cs-137 for sediment and sea water in the predanubian sector as well as along the western Black Sea coast, the evolution of sediment and sea water contamination off the Danube mouths is illustrated by concentrations of Cs-137 immediately after the accident (Fig 1)

In the Romanian Black Sea sector, the maximum values of Cs-137 in sea water and fish were found in 1986, macrophytas and molluscs in 1988, and in sediment in 1987 (Table II) In all samples Cs-137, persisted from 1987 until 1995

The concentration abilities of various marine biota for artificial post - Chernobyl radionuclides was previously commented [2, 3, 4, 5, 7, 9, 10, 11, 12] Thus, for example, pelagic fish species showed the following distribution of Cs-137 concentrations *Sprattus sprattus phalericus* > *Merlangius merlangus euxinus* > *Trachurus mediterraneus ponticus* > *Engraulis encrasicolus ponticus*, due to distinctive feeding manners These species are the most important in the present Romanian marine fishing and directly or indirectly envolved in human consumption

Concentration factors were also computed for Cs-137, as radionuclide of major interest following the Chernobyl accident [10, 11, 12] (Fig 2) The maximum values have been obtained for the sediment at the Danube mouths The additional radioactivity from the river contributions has increased the local impact of the accident [11, 13]

With time the content of artificial gamma radionuclides continuously decreased in all components (sediment, sea water, biota) compared to 1986 E g, Cs-137, decreased comparatively with its maximum concentration in 1986 up to 63% during 1987-1988 This decrease was more gradual during 1990-1991 than it was before The relatively slow decrease of Cs-137 concentrations in sediment compared to sea water confirmed the ability of sediments to concentrate radionuclides

Although decreasing considerably between 1986-1988 Cs-137 levels in the NW Black Sea have not yet reached the pre-Chernobyl values [5] A Cs-137 residence time of about 15 years has been estimated from a simple model The evolution of Cs-137 concentrations in sea food following the

Table I: Isotopic ratios and distribution coefficients (K_ds) of some gamma radionuclides in sediment and sea water of the predanubian sector of the Black Sea in 1986 (May,1)

Transect	Sampling depth (m)	Sediment		Sea water	K_d ($l.Kg^{-1}$)	
		$^{106}Ru/^{103}Ru$	$^{137}Cs/^{134}Cs$	$^{137}Cs/^{134}Cs$	^{40}K	^{137}Cs
Sulina	10*	0.3+0.1	2.1+0.1	2.5+1.1	100+11	1826+375
	20*	0.2∓0.1	2.4∓0.1	1.8∓1.8	135∓16	2136∓875
Sf.Gheorghe	10*	0.3∓0.1	2.1∓0.1	1.9∓0.5	107∓ 9	985∓ 91
	20*	0.2∓0.1	3.2∓0.3	1.7∓0.5	133∓11	879∓184
Portita	10**	0.1∓0.1	2.3∓0.1	2.2∓1.0	50∓ 6	299∓ 46
	20*	-	-	1.0∓0.3	144∓26	259∓ 8
Buhaz	10***	0.4+0.3	2.0+0.2	1.1∓0.8	27∓ 3	675∓338
	20**	-	2.6∓0.3	1.5∓0.3	47∓ 4	70∓ 4

Sediment: * muddy, ** muddy with mollusc shells, *** sandy.

Table II: Maximum Cs-137 concentrations in environmental samples from the Romanian sector of the Black Sea (1983-1995)

	Emerged sediment Bq/kg dry	Submerged sediment Bq/kg dry	Sea water Bq/l	Macro-phytes Bq/kg fw	Molluscs Bq/kg fw	Fish Bq/kg fw
1983	-	-	0.04	2.2	-	2.6
1984	4.8	-	0.03	3	-	3.3
1985	3.7	-	0.03	-	-	-
1986	29.6	-	0.85	-	4.4	44.4
1987	18.9	247.0	0.13	4.6	3.2	11.0
1988	11.5	25.2	0.10	7.1	3.3	4.3
1989	15.5	-	0.09	5.2	2.8	5.1
1990	13.3	55.0	0.07	3.4	1.3	4.0
1991	21.5	24.2	0.08	1.9	1.5	3.9
1992	10.7	-	0.06	1.4	1.2	3.5
1993	8.2	189	0.12	2.8	2.3	4.2
1994	-	150	0.07	-	-	-

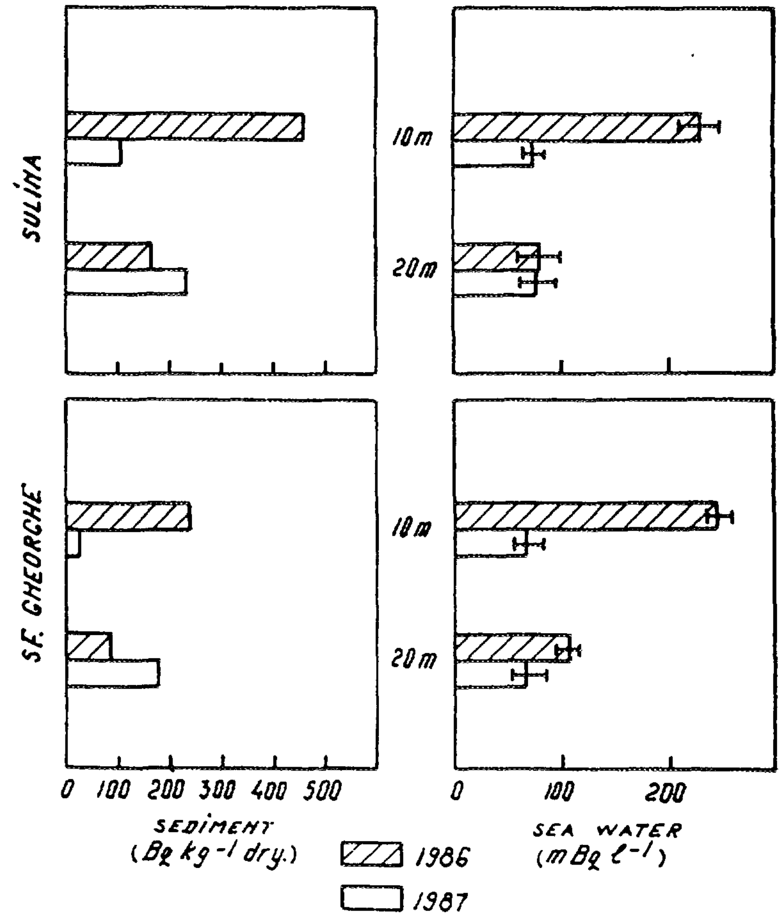

Fig.1 Cs-137 concentrations in sediment and seawater off the predanubian coast during 1986-1987.

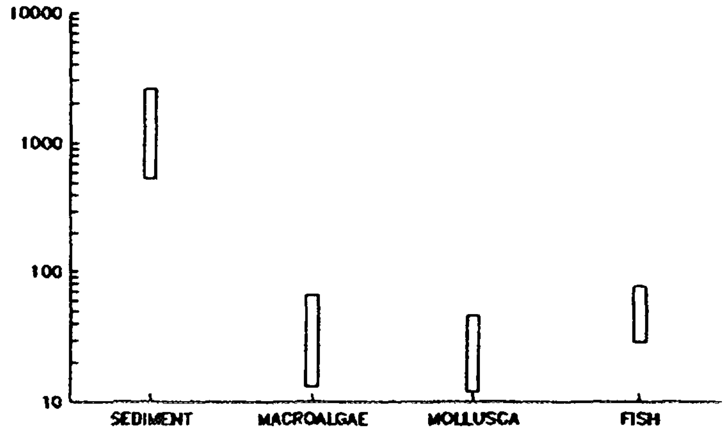

Fig.2 CFs intervals for marine components.

Chernobyl accident is an important component of the Romanian monitoring program, the highest Cs-137 and Cs-134 *concentrations in edible marine biota (fish, molluscs), in the Romanian sector*, allowed for food by the United National Food and Agriculture Organization (FAO) in 1987 and the following years did not exceed the "action levels" or maximum admissible limits

The data on gamma radioactivity of the marine littoral ecosystem permitted estimates of annual individual external and internal radiation doses before and after the Chernobyl accident (Fig 3) [14, 15, 16]

The systematic indigenous research activities and results in the field of marine radioactivity have been partially revaluated within the IAEA research contract No 4805/ROM/RB/1987-92 "Monitoring of marine water, sediment and biota radioactivity in samples from the Romanian sector of the Black Sea by means of gamma spectrometry" [8] Certain results obtained under the above mentioned research contract were used through the IAEA research agreement No 302-K4-ROM/1989-92 "Dose assessment from marine radioactivity in the Romanian sector of the Black Sea" for the IAEA/MEL CRP "Sources of radioactivity in the marine environment and their relative contributions to overall dose assessment *from marine radioactivity - MARDOS" [4]*

More recent gamma radioactivity measurements along the Romanian shore have been used for the computation of the radiological exposure of the European Community to radioactivity in the framework of the MARINA-MED project [9]

Marine radioactivity data will also complete the international Co-operative Marine Science Program in the Black Sea (CoMSBlack), launched as first regional oceanographic program after 1990, by its working group on marine radiochemistry and radioecology [17]

A Romanian data base for radionuclides in the north-western Black Sea has been developed to include the results of the monitoring program performed by RMRI and RLER beginning with 1984 [18] This data base was also used for ICSEM/GIRMED and IAEA/GLOMARD marine radioactivity data bases [5]

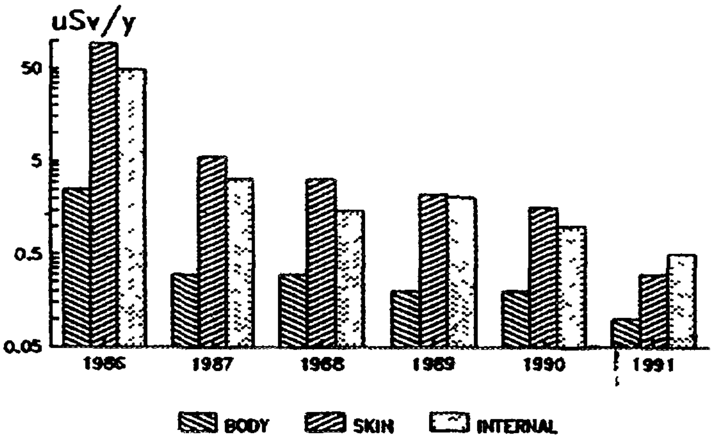

Fig 3 Maximum total doses for external and internal exposure

4 CONCLUSIONS

-The occasional or continuous monitoring of alpha, beta and gamma radioactivity in the romanian sector of the North-Western Black Sea has enabled the establishing of reference values for all categories of marine components

-The Chernobyl nuclear accident caused increases of artificial radioactivity for the abiotic and biotic components, with maximum values in 1986 and 1987

-Nowadays there is a tendency of coming back to the environment condition before 1986

-The Danube mouths produce an additional impact zone owing to the Danube contribution

-The sediment, algae, molluscs and fish significantly concentrate artificial radionuclides, in accordance with environmental concentrations

-There is a remarkable remanence of Cs-137 in the substratum, as a witness of recent human nuclear history (1987-1994)

-The level of maximum individual exposure to the marine external and internal irradiation is inferior to the national and international standards for 1986-1991

-National (RADMAR) and international (GIRMED, GLOMARD) data bases have been made up for various uses

-The knowledge on the actual marine environment condition is required for the characterization of the impact of some future nuclear activities and objectives near the Romanian Black Sea coast (Cernavoda, Danube-Black Sea canal, Constantza-Agigea)

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Acknowledgements

Sincerest gratitude is hereby expressed to Drd C Dovlete / REIE Bucharest and Drd Iolanda Osvath / IAEA-MEL Monaco for their fruitful and permanent scientific and technical co-operation in the field of marine radioactivity monitoring

THYROID EQUIVALENT DOSE FOR CHILDREN UP TO FIVE YEARS OLD AND ADULTS IN THE REPUBLIC OF SLOVENIA AFTER THE CHERNOBYL ACCIDENT

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XA9745880

1. Introduction

First increased levels of contamination in air and fallout was measured on Wednesday morning, April 30th 1986. Maximal value of the gamma dose rate was 1.2 μGy/h on the May 1st and then slowly decreased to 0.3 μGy/h at the end of the second week in May 1986 [1,2]. Maximal concentrations of gamma emitting radionuclides measured in air and fallout ranging from 0.3 kBq/m^3 to 10 kBq/m^3, with exception of ^{131}I, which had the maximal value on May 1st, 25 kBq/m^3, then concentration slowly decreased to 0.5 kBq/m^3 on May 8th. At the end of May no ^{131}I in air was present. The highest concentration of ^{131}I in fallout was measured on May 3th, 30 MBq/m3, then decreased to few hundred on May 15th. Concentrations of radionuclides in grass were in range from 0.3 kBq/m^2 to 15 kBq/m^2. Specific activities of ^{131}I in different foodstuffs like fresh milk, beef, fruits and leafy vegetables in first months after accident in Chernobyl were in range from few Bq/kg to 9 kBq/kg (Table I).

In first two weeks after Chernobyl accident the most dangerous radionuclide for inhalation and ingestion was ^{131}I. Our government suggested to stay in closed apartments, especially for children and pregnant women. The usage of fresh fodder for cattle and other domestic animals was restricted because of possible high contamination of milk with ^{131}I.

Table I. Specific activities of ^{131}I in different foodstuffs in 1986 in Bq/kg

Month	May		June		July	
Foodstuff	max	average	max	average	max	average
Milk	2000	150	45	17	5	3
Meet	65	10	5	3	-	
Fruits	440	130				
Vegetables	9200	1200				

2. Results

Air, fallout, foodstuff and other samples were taken on different locations in our country. All measurements of specific activity of radionuclides based on gamma spectroscopy with high purity Ge detectors.

On the basis of previous data monthly thyroid equivalent dose for children 5 years old and adults by inhalation and ingestion was estimated. The methodology based on the ICRP 30 and on the computer program, made at the Institut für Strahlenhygiene, BGA, München, Germany [3].

Maximal doses estimated were on May, 15 mSv and 3.2 mSv for children and adults, respectively (Table II). Thyroid equivalent dose by inhalation of I-131 of 0.95 mSv for children and 0.3 mSv for adults was estimated. Then dose slowly decreased to few µSv in August 1986. If we assume recommendations, not to drink fresh milk and not to eat leafy fruits and vegetables, the thyroid dose by ingestion of 2.8 mSv for children and 0.5 mSv for adults was estimated.

Table II. Monthly thyroid equivalent doses for children and adults in mSv

Month	Children		Adults	
	Ingestion	Inhalation	Ingestion	Inhalation
April	0.31	0.05	0.04	
May	15	0.95	3.2	0.3
June	2.7	0.04	0.46	0.01
July	0.31		0.06	
August	0.02		0.03	
Sum	18.3	1	7.7	0.3

3. Conclusions

We assume that many people which were living in villages didn't use governmental recommendations at the beginning, so the real doses are between the doses mentioned above.

From the risk calculations [4] for thyroid cancers for children we can expect 10 to 18 cases in next 50 years or 30 % probability for 1 case/year for children which were 5 years old in 1986. Mortality is 10 times lower, so we can expect only few deaths caused by nuclear accident in Chernobyl.

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ASSESSMENT OF DOSE CONTRIBUTION TO POPULATION EXPOSURE FROM THE RADIATION SOURCES IN THE ALIENATED CHERNOBYL ZONE

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XA9745881

The main dose load on ukrainian population is caused by radionuclide-contamination of country territories, located outside the alienated zone, following Chernobyl accident. Besides, much attention could be devoted to the contribution of dose load on population, received from the radiatioactivity sources that were transferred out from the zone after accident. Present research and analysis of the available documents reflecting the transfer of radioactivity from the alienated zone, provided the estimates of dose load on population, resulting from transfer of the radioactivity sources via following channels: (1) direct surface flow; (2) underground waters; (3) wind-powdered route; (4) transfer with hydrobionts; (5) transfer during irrigation; (6) biogenic route; (7) transport routes and (8) route during wood transportation. Dynamics of radioation transfer through the each channel was also studied for the post-accident period. Specific gravity of radioactivity transfer is determined in relation to dose load on ukrainian population in different regions, in particular, in Dnipro river basin. The perspectives of radiactivity transfert via each of studied channels and its role in dose load on population were also analyzed. On the basis of present results the recommendations on possible arrangements are working out that aimed to reduce the dose contribution in population exposure by radioactivity source transferr from the alienated zone via channels that stipulate the largest dose loads and collective doses.

RADIONUCLIDE MIGRATION PROCESSES IN THE RIVERS OF THE DNEPR-SOZH BASIN IN BELARUS

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МИГРАЦИИОННЫЕ ПРОЦЕССЫ РАДИОНУКЛИДОВ В РЕКАХ ДНЕПРОВСКО-СОЖСКОГО БАССЕЙНА БЕЛАРУСИ

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В результате аварии на Чернобыльской АЭС радиоактивному загрязнению на территории Беларуси подверглись реки Днепровско-Сожского и Припятского бассейнов. Основные источники загрязнения рек: в начальный период - непосредственное выпадение радионуклидов на водную поверхность, в дальнейшем - смыв радионуклидов с загрязненных водосборов, поступление их из донных отложений в результате процессов десорбции и взмучивания, ветровой перенос с загрязненных участков водосборов, отмелей и т.д. Перенос радионуклидов водным путем происходит в растворимой форме, на взвесях и транспортируемыми наносами. Проводимые наблюдения на реках Беларуси показали, что среднегодовые концентрации радионуклидов, начиная с 1986г. по 1995г., снизились, но относительный вклад стока радионуклидов, ассоциированных со взвешенными наносами, увеличился.

Изучена динамика уровней загрязнения и выноса радионуклидов через наблюдаемые створы в реках Днепровско-Сожского бассейна за период 1987-1995г.

Для изучения закономерностей переноса радиоактивного загрязнения в речной сети в качестве экспериментального был выбран наиболее загрязненный водосбор реки Ипуть с контрольными створами в д.Вылево и г.Добруш. На основе обобщения данных мониторинга, натурных исследований расчетным и экспериментальным путем получены эмпирические коэффициенты, необходимые для прогноза миграции радионуклидов в реках. Рассчитан сток и вынос цезия-137 на взвешенных наносах через створ г.Добруш (1992-1995 г.).

В результате проводимых исследований показано, что в следствие нестационарности процессов в речном русле происходит седиментация взвешенных наносов на участках с замедленным течением реки. Это приводит, в свою очередь, к образованию локальных, подвижных экологически опасных центров скопления радионуклидов в донных отложениях речных пойм. отмелей, водоемов перед плотинами. Появление таких участков скопления радионуклидов требует проведения регулярного мониторинга и прогноза по их выявлению, принятия водоохранных мер.

XA9745883

THE PROBLEM OF RADIOACTIVE CONTAMINATION INHOMOGENEITY AND SIMULATION OF THE TRANSPORT OF RADIONUCLIDES THROUGH AGROECOSYSTEMS

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The analyses of the measurement data on the territory of the Ukrainian Polesie region carried out by the Research Centre Julich and the Ukrainian Institute of Radioecology shows that there is a high degree of inhomogeneity for the contamination pattern, the transfer from soil to the biosphere and for the food consumption. Therefore, a deterministic environmental assessment model may not be convenient because most processes are not known in detailed. In this situation a probabilistic approach seems to be more promising.

In this report presented a dynamic model for the transfer of radioactivity in terrestrial food chains that fit to the regionally conditions and agricultural practice.

The living organism will be treated as dynamic system subject to random action of radioactivity. This system is described by stochastic differential equations of Langevene's type. Starting from this base we calculated a distribution function of radionuclide body burdens for inhabitant ensembles under the assumptions that entering of activity into organism is a random temporary function that can be approximated by certain impulse Poison processes.

A comparison of calculated distribution function is carried out with measurement results of internal body burden. It shows a satisfactory description of the real situation found for four investigated villages of Ukrainian Polesie region (Olevsk, Narodichi, Vezhitsa and Stare Selo) that were characterised by different degree of contamination and different degree of inhomogeneity.

SESSION 6

DESTRUCTIVE EFFECT OF THE CHERNOBYL ACCIDENT ON LIFESTYLE AND SOCIAL STRUCTURE

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ДЕСТРУКТИВНОЕ ВОЗДЕЙСТВИЕ ЧЕРНОБЫЛЬСКОЙ КАТАСТРОФЫ НА ОБРАЗ ЖИЗНИ И СОЦИАЛЬНУЮ СТРУКТУРУ

Принципиальное своеобразие Чернобыльской катастрофы состоит в комплексном и пролонгированном деструктивном воздействии на все стороны жизнеобеспечения и жизнедеятельности человека, которые охватываются интегративным понятием "образ жизни". О негативной динамике такого воздействия свидетельствует следующий возрастающий ряд тревожных квантификаций: в апреле 1987 г. в районах Беларуси, пострадавших от радиации, обеспокоенность состоянием здоровья высказывали 55,5% опрошенных, в апреле 1991 г. -- 67,8%, в сентябре 1995 г. -- 83,2%. Отвечая на вопрос, как изменилось состояние здоровья за 10 лет после катастрофы, только 2,7% респондентов отметили его улучшение, 14,9% констатировали, что оно практически не изменилось, зато 76,4% утверждают, что оно ухудшилось. Причем 60,8% опрошенных убеждены, что их здоровье ухудшилось из-за радиационного загрязнения местности, 49,2% -- вследствие отсутствия необходимых лекарств, 38,4% -- плохого медицинского обслуживания. Только 8,5% респондентов связывают ухудшение своего здоровья с возрастом. Естественно поэтому, что более половины опрошенных -- 56,4% -- считают необходимым направлять средства, выделяемые пострадавшим регионам, главным образом на лечение тех лиц, которые в этом нуждаются.

Ухудшение общего социально-психологического фона, на котором развертывается жизнедеятельность людей в пострадавших от Чернобыльской катастрофы районах, особенно негативно сказывается на женщинах-матерях, которые подвержены длительным радиоэкологическим стрессам в полтора-два раза сильнее, чем все остальные группы населения. Только 3,6% опрошенных женщин удовлетворены масштабами и результативностью работы по ликвидации последствий катастрофы в зоне их проживания, частично удовлетворены — II,5%, совершенно не удовлетворены — 63,2%. Главный объект тревожности — здоровье и будущее детей. Две трети опрошенных матерей выражают сильную озабоченность по этому поводу. Чем выше социальный статус женщины — ее образовательный, профессионально-квалификационный уровень, степень культурного развития, тем сильнее озабоченность как здоровьем детей, так и их будущим.

Тревожность матерей по механизму эмоциональной карусели передается детям. От трети до половины школьников в зоне радиоактивного загрязнения, как и их мамы, опасаются за свое здоровье. Каждые четверо из десяти опрошенных школьников Гомельской и Могилевской областей убеждены, что раз они в будущем имеют больше шансов заболеть, чем их сверстники, то им "не светит" интересная, привлекательная работа. Только 8% из них считают достаточными свои возможности для поступления в университеты, зато в четыре раза большее количество ставит в качестве своей жизненной установки стремление найти любую работу. Снижается качество учебы школьников по сравнению как с предыдущими годами (учились на "хорошо" и "отлично" в I99I-I992 гг. 30,6%, в I994-I995 — I7%,на "тройки" — соответственно I6,6% и 28,6%), так и со сверстниками экологически чистых районов (больше "троечников", чем в экологически чистом районе Гродненской области на 6-8%, а хороших учеников — меньше на 7-9%). Кроме того, у I0,9% детей в загрязненных районах зафиксировано ухудшение их отношений с родителями, что приводит к более широкому (на 8-9%) распространению здесь конфликтов родителей с детьми. Одной из причин возрастающего числа семейных конфликтов становится алкоголизация. В 1991 г. связывали семейные конфликты со злоупотреблением родителями спиртными напитками 13,8% опрошенных подростков, в 1995 — 22,3%. В экологически чистом регионе только 10,1% детей, вдвое меньше, назвали эту причину. Рост численности семейных конфликтов отрицательно сказывается на всех сторонах жизни как детей, так и взрослых.

Спустя десять лет после ядерного взрыва социальная защита остается основным полюсом напряжения в социальных ожиданиях населения. В сентябре 1995 г. низким уровнем социальной защиты "чернобыльцев" было обеспокоено 84% респондентов, а в сильно загрязненном (40 и более кюри на кв.км) Хойникском районе Гомельской области этот показатель составил даже 89,5%. Более половины опрошенных (52,8%) не удовлетворены продолжительностью отпуска, положенного для лиц, пострадавших от радиационного воздействия, 54% обеспечением чистыми продуктами, 45% — системой оздоровительных мер, 49,4% — дополнительными выплатами и льготами для населения, проживающего в радиационно загрязненных районах. Количество частично удовлетворенных этими важнейшими аспектами социальной защиты людей, пострадавших от катастрофы, колеблется в пределах 32-44%, а вполне удовлетворенных еще меньше: от 4 до 15% от общего количества опрошенных.

Многообразные негативные посткатастрофные процессы оказывают деструктивное воздействие на основную сферу образа жизни — трудовую. Практически каждые шестеро из десятерых (59,2%), проживающих на загрязненных территориях, обеспокоены содержанием и условиями своего труда. А в Хойникском районе количество неудовлетворенных трудовой деятельностью достигает 71% от общего количества опрошенных. Характерно, что при общей численности нуждающихся в улучшении условий и оплаты труда, выражающейся в 58% от общего количества респондентов, в Хойникском районе этот показатель возрастает до 67,3%, т.е. почти на 10 пунктов. Особенно остро реагируют на плохие условия труда медицинские работники, от профессиональной деятельности которых в пострадавших районах в наибольшей степени зависит не только самочувствие, но и качество жизни людей в целом. 78% из них убеждены, что размер заработной платы находится ниже социально приемлемого уровня. Поэтому 72% медработников вынуждены искать дополнительные заработки, что снижает качество их профессиональной деятельности, 68,5% не удовлетворены организацией питания по месту работы, столько же — санитарно-бытовыми условиями труда, 55,4% — укомплектованностью рабочих мест оборудованием, инструментами и другими средствами для оказания медицинской помощи. Все это снижает качество их профессиональной деятельности. Аналогичные тенденции в трудовой сфере выявлены и у работников промышленности, строительства, сельского хозяйства. Несколько более благополучной представляется трудовая ситуация работникам торговли, бытового обслуживания.

Под влиянием Чернобыльской катастрофы и ее последствий подверглись дезинтеграции и ухудшению такие важные компоненты образа жизни, как культура, образование, социальная солидарность, самоидентификация. 73,1% респондентов в пострадавших районах обеспокоены ухудшением духовно-нравственной стороны образа жизни, снижением культурного уровня людей, 36,6% — качеством работы детских дошкольных учреждений, 38,6% — деятельностью школ, 76,9% — распадом прежних социостратификационных структур, углубляющейся дифференциацией людей на богатых и бедных. В городах эти тенденции проявляются сильнее. При общем удельном весе обеспокоенных социальным расслоением общества, составляющем 76,9%, в гор.Гомеле этот показатель достигает 82,2%.

Если суммировать негативные тенденции в ухудшении различных сторон образа жизни в посткатастрофный период, то картина общего социального неблагополучия рельефно выражается интегральным показателем — количеством людей, имеющим право на получение статуса пострадавшего. Только в Гомельской области таких насчитывается 1,4 млн. человек, т.е. 87,5% всего населения. В связи с этим 64,7% обследованных стали смотреть на жизнь и свои перспективы в будущем пессимистически.

Такое мироощущение в значительной мере обусловлено негативной динамикой социальной структуры. В пострадавших районах за десятилетие, прошедшее после катастрофы, численность трудоспособного населения сократилась на 15-16%, резко ухудшилась социальная структура. Вследствие миграции в экологически чистые районы существенно (на 12-14%) сократилось количество дипломированных и квалифицированных рабочих, специалистов в промышленности,строительстве, сельском хозяйстве, здравоохранении, образовании,культуре. В сельскохозяйственном производстве уменьшился слой квалифицированных работников-механизаторов. Усилилась люмпенизация населения; выпадение многих из социально престижных и обеспеченных социальных структур: доля людей, живущих на пороге бедности, достигает 67%.

Негативные изменения в социальной структуре и образе жизни ведут к широкой распространенности дезадаптационных стратегий поведения. Только 44% населения, проживающего в загрязненных регионах, адаптировались в той или иной степени к новым условиям жизни, а почти половина — 49,4% подвержены дезадаптационному поведению. В итоге нарастает социальная напряженность, конфликтогенность, активнее других распространяются конфликты населения с властями, что констатирует 39% респондентов. Вывод: нужны более активные реабилитационные мероприятия в социальной сфере при приоритетном внимании социальной поддержке пострадавших людей.

INTERNATIONAL UNION OF RADIOECOLOGY RESPONSE TO THE CHERNOBYL RADIOECOLOGICAL SITUATION

XA9745885

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1. INTRODUCTION

UIR main objective , as NGO and international scientific association of more than 500 members working in 255 organizations from 37 different countries,is to encourage the exchange of information and expertise in the field of radiecology,particularly in case of major accidental release of radioactive materials,such as the Chemobyl accident(1986 April,26th) which raised the problem of a contamination on a large scale.This primary objective of UIR is not restricted to information on the transfer of important radionuclides in the environment but includes information which can aid in understanding the impact of radiation exposure on populations of living organisms and ecosystems.The response of UIR to the Chemobyl accidental situation occured in various manners,taking advantage of the structure and the potential of the organization.

2. SPECIFIC RESPONSES TO THE CHERNOBYL ACCIDENTAL SITUATION

2.1 Increase of contacts and cooperation with CIS scientists

UIR teams visited the contaminated areas and discussed with local scientists e.g. 5 UIR representatives spent 10 days (7-17 May 1990) in ex-USSR;-.The special radioecological problems at Chemobyl were identified primarly as "The Red Forest" and "The Floodplain of the River Pripiat ".

The most important radioecological tasks at Chemobyl were, according to our hosts colleagues, the following.

(a) To map the radioactivity levels and to study the effects of resuspension.
(b) To identify efficient countermeasures,e.g. by recultivation of the soil.
(c) To investigate the migration of radionuclides, e.g. run-off to the river.
(d) To study the radiation effects on trees, e.g. somatic mutations.
(e) To investigate the hot particles and other inhomogeneities of the contamination.
(f) To study the root uptake of radiocesium and other radionuclides in order to explain why the root uptake has been increasing with time . This increase may be due to increasing solubility of the particles in which the radionuclides are inbedded, but irrigation may also be an explanation .

This first UIR radioecological expedition to the former USSR was a success. At the three locations visited ,The Black Sea,The Urals and Chemobyl, western scientists worked together with their eastern counterparts and collected samples which have been divided between the laboratories of the participants for intercomparison of radioactivity measurements At every place,the visitors were met with an overwhelming openness and felt a great interest in contacts and cooperation.

Intercomparison exercices are an important part of any radioecological cooperation.This first expedition has been an excellent beginning..A number of samples collected were analysed by both CIS and western Laboratories in order to compare the results obtained by radiochemistry as well as by gamma-spectroscopy.

In the framework of a mutual agreement ,9 Soviet scientists visited, in October 1990, various radioecological laboratories located in Belgium,France,United Kingdom and Denmark.One of the main purposes of this agreement was the monetary exchange restrictions: the expenses of the visiting team were supported by their hosts.This approach worked in a very satisfactory way.

In its report EUR 15229 EN on " Evolution,achievements,perspectives" dealing with the Radiation Protection Programme 1987-92 and Post-Chernobyl Actions 1988-89, the Commission of the Europen Union recognized: "The efforts of the International Union of Radioecology in the past period are fully appreciated especially the role it has played in prospecting the relevant scientific situation in the former Soviet Union. This has been extremely useful when our Action had to establish its own contacts in relation to the planning of our research with CIS authorities and Institutions".

A delegation of UIR members visited the MAYAK Production Association during June 1993 stimulating the production of a protocol stressing the need for development of bilateral and multilateral co-operation in applied and general radioecology for the restoration of nuclear sites in Europe.A number of proposals for joint work were elaborated and it was agreed that there is a need to establish an international centre for environmental restoration.UIR has subsequently worked to bring the resulting agreement to the attention of the scientific community and to the potential funding organisations.

2.2. Organization, usually in collaboraton with intergovernmental Institutions, of international scientific meetings

A Seminar CEC-UIR on "Comparative Assessment on the Environmental Impact of Radionuclides released during three Major Nuclear Accidents:Kyshtym,Windscale,Chernobyl" was held in Luxembourg, in October 1990 : 200 participants ,including 46 Soviet scientists ; attended it [1].

Another Seminar on "Radioecology and Countermeasures",organized by the UIR Soviet Branch,was held in Kiev (Ukraine),27 April-4 May 1991;68 scientists attended this meeting [2].

The same year a CEC-UIR Seminar on the intervention levels and countermeasures was held in Cadarache (France) :140 participants,including 23 CIS scientists, attended this important meeting [3].

A Seminar, co-organized by CEC-UIR -SCSR, on "Chemical Speciation-Hot Particles"was held in Znojmo,in October 1992 [4], whereas a Workshop,organized by the UIR European Branch and sponsored by the European Commission,on" Radioecology: Advances and Perspectives" took place in Sevastopol (Crimea) 3-7 October 1994.This latter meeting provided an opportunity for radioecologists from many former Soviet Union laboratories to renew and strengthen their contacts.Many aspects of radioecology were discussed and the meeting allowed for discussions on the scientific basis for decision-making in the New Independent States.

2.3. Synthesis reports dealing with impacts of the Chernobyl fallout

The following seven reports were prepared for the European Commission, Directorate-General XI Environment, Civil Protection and Nuclear Safety .

2.3.1. Agricultural Countermeasures taken in the Chernobyl Region and Evaluation of Results April 1990 ,[5].

In carrying out this study,a major obstacle had to be overcome right at the start,namely the problem of obtaining access to publications,usually in Russian, relating to field observations and experimental results obtained by the agro-ecological stations established in the contaminated region of Chernobyl from August 1986 onwards.It became soon apparent that the best solution would be to obtain help from Soviet colleagues who took part in the scientific work undertaken after the accident at the Chernobyl nuclear power station.

Collaborative arrangements were therefore made and furthermore a Workshop was organized at LIège on 19-21 June 1989,with the active participation of Soviet, North American and European Community representatives .

2.3.2. Radiological Analysis of the 1957 nuclear accident in the Urals and its possible impact on E.C.Members States ,Sept.1990, [6].

This study addressed two major objectives,(a) to determine the exact nature of this accident,and the radiological and radioecological impacts resulting from the releases to the local environments.Additionally it would attempt to bring together data and information on the nature and extent of the countermeasures that were developed there,as it is known that Soviet radioecologists who had participated in the Urals cleanup were called out to assist at Chernobyl;(b)the second objective had the purpose of investigating the geographical dispersal of the radionuclides from the nuclear facilities in this region A summary of this study was presented at the Luxembourg Seminar [7]

2.3.3. Impact radioécologique de l'accident de Tchernobyl sur les écosytèmes aquatiques,
a) outside the Former Soviet Union ,Sept.1989,[8], b)within the Former Soviet Union ,Sept.1991,[9]

This review is based on 330 publications.The radioactivity is directly related to the level of deposits which were ,essentially, in wet form.The peak in river water occured very soon after the accident and was of short duration ,due to dilution Nevertheless in lakes this decrease was much slower In sediments the radioactivity varied in time owing either to new deposits to the migration of those deposits downstream in the river basins The river fish were only subjected to water and food with high levels of radioactivity for a very short time so their radiocesiums concentrations remained fairly low In the case of lake fish,differences in the levels of radiocontamination were observed according to the regions and rate of fallout

It is worthwhile to mention that the levels of contamination ,reached in the aquatic environment, after the Chernobyl accident, was one to two orders of magnitude higher than those observed after the atmospheric nuclear tests between 1956 and 1964

2.3.4 Assessment of the strontium-90 content in the agricultural produce originating of the areas of the USSR contaminated by the Chernobyl accident: April 1992 ,[10]

As mentioned above,in October 1990 a seminar took place in Luxembourg dedicated to the comparative assessment of the environmental impact of radionuclides released during the Kyshtym,Windscale and Chernobyl accidents

The analysis of the papers presented at this seminar as well as other post-Chernobyl evidence prompted Directorate-General XI to focus attention on the impact of strontium-90 on the environment after Chernobyl and in particular,to collect all data related to this isotope with a view to gain knowledge on the medium and long term contamination by strontium-90 of the foodstuffs originating from the contaminated areas.

2.3.5. Behaviour of accidentally released radiostrontium into Environment. Effectiveness of countermeasures. Nov.1993;Final report.,[11]

As very few food contamination data on strontium were reported during the above mentioned Luxembourg seminar and as,furthermore, these data mainly concern a period of time during which secondary deposition on the vegetation may have played a significant role,data collection was enlarged to other sources such as the papers presented at the seminar organized by UIR in Kiev (see above) and the report of the International Advisory Committee of the IAEA.

Among the conclusions and recommendations , the final report amply underlined and discussed the problems linked to the values quoted for the various transfer coefficients . It is concluded that the situation is quite unsatisfactory : few values are quoted with enough details about the way in which they were obtained to allow any serious judgement about their reliability.Here also ,more efforts should be made to spell out the minimum information requirements. Soils data are,in this respect,in need of the greatest improvement.

*2.3.6. Effects of Countermeasures on Radionuclides Transfer to Animal Products.*April 1992; [12]

The objectives of this study were to:

(a) Collate published and unpublished data on the effects of countermeasures on radionuclide transfer from diet to animal products

(b) Provide practical recommendations for measures in different agricultural systems that could be implemented after a nuclear accident.

(c) Provide best-estimates and ranges for reduction factors that can be incorporated into radiological assessmemt methodologies.

One of the main conclusions is that,in general,the majority of published literature on the use of chemical countermeasures for controlling radionuclide concentrations in animals products relates to rather simple observations on the effects of a potential binding agent on concentration in milk or meat.Further progress in identifying agents that can be used in practical circumstances requires fundamental research on the metabolism of radionuclides of importance in farm animal and of the factors affecting metabolism in different animals.It also required that the potential costs of environmental effects of chemical countermeasures be assessed to offset them against the potential benefits.

2.3.7. La contamination radioactive du théier:étude de synthèse. ,Oct.1994.[13].

The aim of this study was to gather the data on the contamination of tea-trees by radiocesium arising from the Chernobyl accident.It considers first the ecology of the plant,the various preparations of this beverage and its consumption. In the second part of the report an evaluation of the costs to destroy the contaminated tea, by means of classical waste management (landfill,ashing), is presented .

3. COLLABORATION WITH OTHER INTERNATIONAL ORGANIZATIONS/ PROJECTS

3.1 SCOPE-RADPATH

The aim of this project under the auspices of the Scientific Committee on Problems of the Environment(SCOPE) was to collate information on biogeochemical pathways for the transport of artificial radionuclides in the environment.The results of this project have been published as SCOPE 50 Report("Radioecology after Chernobyl") in which the considerable contribution of UIR to the SCOPE-RADPATH project is acknowledged.

3.2. UNESCO-CESN

UIR has continued to maintain close contacts with UNESCO during the development and implementation of the Chernobyl Ecological Scientific Network (CESN). CESN acts as a decentralised network of scientists and research institutions for the sharing of information, research and training facilities.UIR members have participated in a number of meetings organised by UNESCO-CESN and are playing an active role in stimulating the contacts and exchange of information necessary to fulfil the objectives of CESN.

3.3 IAEA

UIR was previously an active contributor to BIOMOVS I and continued to bring the expertise of its members to BIOMOVS II and VAMP,the aim of these projects being to provide opportunities for the testing and validation of models used to describe the transport of radionuclides through ecosystems from source to man.UIR also participated on a small scale to the International Chernobyl Project launched in 1990 by the IAEA .It is also worthwhile to mention the recent publication of a joint IAEA-UIR Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Temperate Environment (TRS N°364,Vienna 1994) [14].

4. EDUCATION: TRAINING OF YOUNG SCIENTISTS

The UIR Summer School on Radioecology held in Budapest during July/August 1993 attracted 25 students,8 of which were local and 17 of which came from other countries including five from Eastern Europe.

The Advanced training course in Zarechny (Russia),19-28 June 1995, was intended for all those professionally involved in radioecology and nuclear site restoration.The main emphasis of the course was on specific radioecological problems in severely contaminated areas such as the Southern Urals trace from the Kyshtym accident of 1957,the river Techa-Isert-Tobol-Ob contaminated from discharges at MAYAK from the late 1940's,and the 30 km exclusion zone at Chernobyl. Major problems areas were identified as forests and aquatic ecosystems and attention was focused on the special problems encountered in heavily contaminated areas as a consequence of extreme heterogeneity of contamination and the presence of "hot particles" as experienced after the Chernobyl accident.

5. CURRENT ACTIVITIES

5.1. Effects of ionising radiation on native organisms with special attention to information available from the former Soviet Union

In recent years it has become apparent that there is a substantial body of information in the Russian literature concerning the effects of increased radiation exposure on organisms in their natural environment.These data have been collected both from controlled experiments employing large scale gamma-rays sources and from contaminated areas following serious accidents in the Urals in 1957 and at Chernobyl in 1986.

Intensive work has been undertaken to identify information in CIS on the effects of radiation on native organisms.Subsequently the identified information was collated,translated and analysed by a joint team of Western and CIS scientists.Preliminary conclusions of the review were discussed at a meeting in Budapest in April 1994 and indicated the need for an even more-searching examination of the available literature and a requirement for the study of all-relevant attributes for populations of single species at a range of dose-rates

.As a consequence of the above,an extension to the work of the Task Force (TF5) in charge of this project was sought with financial assistance of PECO (EU funding).Technical work is being undertaken in collaboration with the:

(a) Institute for Biology of the Southern Seas in Sevastopol (Ukraine),
(b) Experimental Research Station at MAYAK, Cheliabinsk (Russia),
(c) Station of General Genetics in Moscow (Russia)
(d) Institute of Agricultural Radiology at Obninsk (Russia).

5.2. Chernobyl Exclusion Zone

UIR continues to co-operate closely with reprentatives of Russia,Belarus and Ukraine responsible for areas affected by the Chernobyl accident.During late 1994 and early 1995,UIR has been responsible for obtaining an agreement signed by representatives of all three States requesting assistance with the development of a programme for an independent assessment of current conditions and environmental safety in the Chernobyl Exclusion Zone.This agreement recognises that there are potential impacts of the Exclusion Zone on nearby territories and that there is a need for a long term management strategy for the zone based on sound scientific principles.UIR is continuing work with reprentatives of all three States to prepare a detailed programme for the work and to identify potential mechanisms for its financing.

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SOCIAL AND ECONOMIC IMPACT OF CHERNOBYL IN TURKEY

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XA9745886

1. INTRODUCTION

The radiological impact of the Chernobyl accident in terms of doses to individuals in the various countries covered a wide range. The specific features of the release of radioactive material from the Chernobyl accident, particularly its relatively large duration and altitude reached by the radioactive plume, caused a widespread distribution of activity across Europe. Meteorological conditions and wind regimes during the period of release were the contributing factors. The varying distances from the source of release and long duration of the release in different directions resulted in uneven ground and foodchain contamination. Also, variable meteorological situation, characterized by frequent and localized heavy precipitation contributed to uneven deposition differs sometimes by one or two orders of magnitude between localities situated few tens of kilometers apart. In these circumstances, the doses to the individuals of critical groups appeared to be higher than the average individual dose over whole population.

2. MATERIALS AND METHOD

The progressive spread of contamination at large distances from the accident site was a considerable concern for most countries in Europe. In Turkey, the Turkish Atomic Energy Authority (TAEA), as the national competent authority, deployed 15 competent personnel to the northwestern region of Thrace on the 30th of April 1986. Airborne radionuclides reached the ground by heavy rain showers on the 3rd May. Upon observation of an increase in the concentration levels from a normal background of air, TAEA recommended taking appropriate actions with a view to making as effective as possible arrangements for the region, in order to reduce the impact of the accident. Advice was given by the 2nd May that fresh rainwater should not be drunk. There was of course a high level of activity on grass. This was expected to be transferred into cows' milk. In May, cattle were already out grazing grass while it was the spring time. In order to minimize the problem of iodine contamination in milk, feeding dairy cows with green forage was stopped and cows were taken from pasture and were fed on supplementary foodstuffs then a ban was introduced on the consumption of fresh milk for about the first three weeks of May 1986. Fresh milk from dairies to the population handed out when the activity of I-131 decreased to 500 Bq/L. One of the most effective action taken was to reprocess dairy milk with higher activities so it was converted into storable dairy products, accordingly, population was less exposed to radiation from milk with a higher I-131 contamination. In the region of Edirne 4000 cattle were quarantined by district government. This was because some breeders had let their animals out to pasture without having knowledge of countermeasures taken.

Special feeding (feed with Caesium free or low fodder) was used for a given period of time. Levels of radioactive caesium up to 4000 Bq/kg were measured in cattle that were put in quarantine. Compensation granted to breeders whose cattle kept in the special feeding program was amounted to about US $ 50000 for eight months [1]. After the program proved to be effective, cattle were approved for slaughtering. Also, the countermeasures ranging from simple advice or recommendations to the public such as washing fresh vegetables and fruits before consumption, up to the adoption and legal enforcement of compulsory measures were taken. In the first week of May 1986, radioactivity released was transported to the Black Sea region of Turkey. Part of the activity that came down on the ground was deposited on plants. That part of country is a climatically favored region where plant growth had already advanced substantially in early May 1986. Hazel, tobacco and tea plants were the most vulnerable ones among the others. Also, these three are very important commodities for both local and foreign markets. Therefore special care was given in measurements of hazelnut, tobacco and tea.

At the beginning of May the caesium isotope, like I-131, adhered to the external surface of plants which could be rinsed off. Later on, the water soluble caesium compounds were incorporated through the leaves' surface and distributed via the plant capillaries This led to fruits and seeds harvested in autumn contain Cs-137 Consequently, leafy plants such as hazel, tobacco and tea showed considerable contamination

For the following years in which uptake by plants of Caesium isotopes from the soil, taking into account that caesium is bound relatively tightly to soil minerals, this uptake through the roots, was small

While efforts are being made, as the lead technical part, by the TAEA, there was also a clear need for organizing a committee dealing with the ways and amplitude of the information to be given to the public, responsibilities to be distributed and efforts to be made fully effective. On the 26th May 1986 the Turkish Radiological Safety Committee was established. The committee was consisted of the TAEA, the Ministry of Health, the Ministry of Agriculture, the Ministry of Industry and Commerce, the Ministry of Environment and Undersecreteriat of Foreign Trade and Treasury. The Minister of Industry and Commerce was the governor of the committee. This committee considerably facilitated enchancing decisions about protective actions ranging from adoption of any countermeasures to compulsory restrictions concerning the commerce and use of foods taking into account that a particular problem raised by the transboundary character of the Chernobyl accident.

In view of air masses containing large amount of radioactive material passed over mainly the eastern part of Thrace and the northern part of Black Sea region of Turkish territory and during the first few critical days, rainfall caused deposition of significant amounts of radioactivity in certain areas, extensive measurement have been carried out on foodstuffs during the first year after the accident. Activity concentrations measured in the most important foodstuffs were found to be safe for consumption. Major part of the country received an almost negligible contribution from the accident. This made facilitated gathering the most important categories of foodstuffs. Efforts were mainly spent to reduce effects of economical impact on hazelnut and tea which contained considerably high activity and were main agricultural products of the Black Sea region. Activity concentration was found to be very low in tobacco.

Radioactivity levels in hazelnut were measured by a laboratory particularly appointed for this task. In accordance with the decision made by the Turkish Radiological Safety Committee, 1986 production of hazelnut was purchased by the Union of Cooperatives of Hazelnut Crop and Production. Thus control over consumption of hazelnut was achieved. Also, taking into account that transboundary character of the Chernobyl accident impacted on the international trade of foodstuffs, a great number of radioactivity measurements on hazelnut carried out and results were classified in three groups based on DIL of 600 Bq per kg adopted by CEC, 2000 Bq per kg recommended by WHO and varied acceptable limits established by some other countries [2]. This facilitated trading of the production of hazelnut for 1986 and allowing 140000 tons of hazelnut to be saved from destruction In addition, the Turkish Radiological Safety Committee decided to raise the action level considering hazelnut is of no importance of forming a significant part of the dietary habits of the Turkish population (annual average consumption is 100 g per capita). Therefore, 5000 tons of hazelnut of which activity limits above 2000 Bq per kg was justified to use in domestic consumption [1].

The main impact of the accident was on Turkish tea It forms an important part of the diet of the Turkish population Most of the Turkish people are in the habit of drinking several glasses of tea on average every day Activity levels up to 30000 Bq per kg for caesium in ready-to-use tea were measured in Autumn 1986 [2]

The Turkish Radiological Safety Committee taking into account consumption of tea is based on brew of tea and considering all the activity is transferred to the brew and a glass of tea is prepared by diluting the brew with added hot water, adopted 12000 Bq per kg for dry (ready-to-use) tea as the highest limiting value. In this case on the bases of the maximum activity concentration assuming a few grams of dry tea is used daily per capita would yield an effective dose amounting to 0 20 mSv for adults per year due to tea consumption was expected for the year 1986 [3]

In order to reduce radioactivity levels for total caesium in tea of 1986, 55000 tons of tea stock in hand from previous year was used for blending in accordance with the decision made by the Turkish Radiological Safety Committee in October 1986.

The process of mixing of tea was carried out under control of the TAEA, within three months, the highest level in tea was reduced to 3000 Bq per kg. After all these countermeasures taken there was still 58000 tons of tea in hand activity concentrations of which was above 12000 Bq per kg [2]. This amount was kept, in about 40 depots of different factories from consuming as a safety measure Afterwards, the Radiological Safety Committee decided the burial of this quantity of tea following a technical report prepared by the TAEA on the subsequent management dealing with disposal alternatives such as incineration and burial.

In 1989, tea in storage was disposed in selected several ground repositories.

The valuation of the disposal of tea which could not salvaged from condemnation was estimated at $ 100 million in the price of 1986. This value represents the main economic loss to the agricultural sector by the Chernobyl accident. During the three years after the accident almost all important foodstuffs were monitored and activity concentration levels for caesium found to be substantially low.

3. RESULTS AND DISCUSSION

In spite of the fact that, when looking back, a significant efforts has been made by the national authorities forming the Turkish Radiological Safety Committee, particularly as the lead technical part by the TAEA, the events and the consequences of the accident were considerably exaggerated and discussed in completely a very emotional way in Turkey. After several years when repercussion of the event began to fade away, some newsmedia from time to time to increase their circulation has deliberately attempted for renewal of public attention bringing forward assertions and allegations that TAEA had been subservient to the government and the limit values especially for tea were laid down too late and further, official measurements gave too low levels which were sanctioned by the TAEA. Moreover, in 1993 an increase in the incidence of leukemia in several provinces were alleged and this was asserted to be related to the radiation exposure due the accident at Chernobyl

The data including pre-Chernobyl incedences was thoroughly examined and the Ministry of Health pointed out that the number falls within normal variation and that there are no incidations of Chernobyl releated leukemia [4].

As for lessons drawn from Chernobyl accident; First, the demand for monitoring was overwhelming. This included monitoring of the environment, of foodstuffs, of the people and so on This show that available resources must be expanded Second, there is a need for better communication with public. It must be explained the doses may be small but the activity is measurable and acceptability of the assumed risk must be taken account

As a result, radiological protection concepts proved to be difficult and contributed to confuse the public about what was safe or simply prudent and what was only the result of misinformed fears and psychological reactions to the accident

The Chernobyl experience has stressed the importance of a national coordination of the emergency management. In view of this, the TAEA prepared the national plan cover accidents occurring neighboring countries and submitted to the approval of related national authorities The plan also gets provincial authorities into emergency response From the point of view that the effects of an accident in a foreign nuclear power plant could require action in any part of the country, the national plan assigns specific responsibilities to the various national authorities Provisions are being made especially for the Armenian VVER nuclear plant located at a distance of about 30 km from the border to Turkey In this context, execution of an emergency exercise has been decided to be incorporated in the national plan

After the Chernobyl accident, an Early Warning Environmental Radiation Monitoring System (EWERMS) has been setup on various locations taking into account their topographical and climatic characteristics as well as distances from nuclear power plants in neighboring countries. At present 32 radiation monitoring stations are under operation and still there is an ongoing project entitled "Strengthening of Radiation Protection Infrastructure in Turkey" aimed at completion of an efficacious environmental monitoring system and updating of regulations with respect to recent developments in radiation protection philosophy.

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XA9745887

ECONOMIC, SOCIAL AND POLITICAL CONSEQUENCES IN WESTERN EUROPE

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It is by now a well established fact that the radiological consequences of the Chernobyl accident are fortunately far less substantial as it has been frequently predicted and claimed in the media (for references, see [1]):

1. There have been so far about 30 identifiable premature deaths due to acute radiation syndrome (less frequent estimates are somewhat higher up to 100 - 200 when including partially radiation-related cases).
2. Of the approximate 700 childhood thyroid cancers that may be attributable to radioiodine emissions, 90 - 95% are curable (many are treated in Western Europe, in particular Germany).
3. No increases in leukemia or other types of cancer, or genetic defects, have so far been detected, nor are they likely based on the evaluation of the Hiroshima and Nagasaki data.
4. There have been no detectable radiation-related effects in Western Europe, or other countries outside the former western Soviet Union.

There may be some late cancers there in future years, resulting in a total number of radiation-related premature deaths eventually reaching one or two hundred. There have also been speculations about additional cancers in large populations in the northern hemisphere exposed to Chernobyl fallout. Assuming the validity of the linear no-threshold radiation effect hypothesis, the multiplication of very small "risks" with very large population number thus yielded figures of 5.000 to 25.000 cancers, in addition to the 40 - 70 millions to be expected in this area during the next 70 years. Such speculations are, and will remain, purely hypothetical, and appear to have little radiobiological substance. Nobel laureate R.S. Yalow recently stated: "No reproducible evidence exists of harmful effects from increases in background radiation three to ten times the usual levels", and a summary of recent data on low-level radiation effects concludes: "Actual scientific data on health effects from low-to-moderate doses of ionizing radiation contradict the presumed linear no-threshold response model" [2].

On the other hand, there have been and remain tremendous psychosocial and economic effects of the accident. In particular in the western parts of the former Soviet Union, against the background of disintegrating structures, have been a distrust of inefficient and corrupt administrators, poor medical services and food supplies, destabilization and serious economic problems of large population groups, losses of agricultural areas, and problems caused by large-scale evacuation and resettlement programs. A large number of psychosomatic and neurological disorders including alcoholism, loss of hair, impotence, even laziness and traffic accidents, have been attributed to radiation effects and strange new deseases such as "chronic radiation sickness" or "radiation AIDS" have been claimed. Most radiobiologists would, however, consider such claims as nonsense, even if some highly indirect relationships may perhaps be established. Unfortunately, many of such problems attributed by some to the Chernobyl accident can also be observed in other parts of the former Soviet Union which have not been affected by fallout. Many people, in particular children, cannot be classified as "healthy" according to the WHO definition, and life expectancy has dropped substantially in many parts of the former Soviet Union in the past decade.

Other and even less likely low-dose effects have been claimed frequently for even less affected areas, e g. increases of birth defects, or damage to animals and vegetation, in Western Europe. Fortunately, such "findings" have never been confirmed by serious investigations. There have, however, been substantial economical, social and political consequences of the Chernobyl accident in this region, of which only a few of the more important ones are listed here:

1. In many Western European countries, there is now much less acceptance of nuclear power than before the accident. For example, the major German (social-democratic) opposition party (SPD), ruling several of the federal states, which had been a strong supporter of nuclear energy in earlier years of the German nuclear prōgram, adopted a strictly anti-nuclear policy shortly after the accident. This led to tremendous economic losses primarily in the SPD-ruled states. The projects which have since been cancelled already represent investments of about 11.000 million U.S. dollars (based on the current exchange rate 1 $ = 1.43 DM). This includes the completed Kalkar Fast Breeder Plant now to be used as an amusement park (5.000 mill.), the operational Hamm-Uentrop high-temperature pebble-bed reactor (3000 mill.), the Wackersdorf reprocessing plant under construction (2.200 mill.), and the almost completed Hanau MOX fuel element manufacturing plant (770 mill.). Other investments including the operational Mülheim-Kärlich NPP (4.900 mill.) and repositories (2.200 mill.) are in acute danger of being permanently shut down for non-technical reasons closely associated with the media's response to Chernobyl [3]. No new NPP is currently under construction in Germany, and the future of the nuclear industry looks far from promising. The total economic losses, in case the 20 NPP providing about 30% of Germany's electricity are closed down as demanded as a post-Chernobyl effect by the second and the third largest political parties, would amount to approx. 180.000 mill. - not including the likely climatic costs due to the increased CO_2 releases.
2. The decision not to continue the operation, or to complete construction of eleven Russian-type LWR power plants in former East Germany after reunification in 1989/1990, and to decommission these plants at an eventual cost of up to 10.000 million, was also strongly affected by a deep distrust against nuclear energy, in particular against all Russian NPP. If upgraded with modern safety systems, at least some of these plants could have served as models for modernizing similar plants in Eastern Europe.
3. Technically unnecessary, politically motivated shut-downs of German NPP have also been very expensive, amounting to 2.500 mill. so far in just one plant (Mülheim-Kärlich). In other cases, excessive delays in the licensing of operation, or of re-starting following routine shut-downs, amounted to 1-2 mill. per day.
4. There are, of course, numerous indirect consequences of such actions. For example,
   - Germany has no new demonstration plants for the possible export of advanced reactor designs to a number of interested buyer countries,
   - valuable scientific and technical know-how is irreversibly lost with the (frequently early) retirement of a whole generation of scientists and engineers in this field, and substantially reduced advanced nuclear training and research, and
   - even very minor nuclear-related activities, e.g. the transport of used fuel elements in an "Castor" cask (considered the probably safest in the world) to a temporary storage facility in Gorleben, leads to antinuclear including criminal activities. The expenses for police protection of the transport of one cask in 1995 (ca. 40 mill.) amounted to more than twice of the total costs of the Finnish repository.

5 Chernobyl strongly contributed to basic changes in the perception and acceptance of minor civilisatory risks by the media, politicians, and the general public, which are not restricted to the peaceful uses of radiation and nuclear energy, but extend into many other areas of technological progress. This resulted in serious problems in the essential dialogue between the economical and political circles in some countries such as Germany, which in turn had a negative impact on the reliability of long-term economic

planning and affects the general investment climate with rather dramatic effects on employment and social stability. It is obviously difficult to quantify such developments in monetary terms, but they are likely to be much larger than some of the more direct Chernobyl effects, such as

- largely unnecessary destruction of produce, milk, etc. (300 mill. in West Germany, including 50 mill. for the "decontamination" of a cattle feed additive), [4], and
- expensive organizational changes, such the creation of sophisticated new national emergency response and radiation monitoring systems, laws, regulations, and standards (in Germany total costs exceeding 200 mill.).

6. Also difficult to quantify are the costs of the psychosomatic stress and anxiety in the general public. For example, estimates of thousands (up to 40.000!) additional abortions in the post-Chernobyl months in Western Europe have been published [5] and seem not unlikely, considering the atmosphere of radiophobic hysteria which had been created in some countries. Late effects include an intensified radiophobia, resulting for example in patients refusing radiation therapy or radiodiagnostics even when they badly needed it.
7. Also not yet finalized are the estimates of the costs for the Western European tax-payers resulting from bilateral and multilateral assistance for clean-up operations and modernizing (or closing down) nuclear facilities in Eastern Europe, establishing and improving regulatory authorities and inspection organisations, etc.. Currently in the range of thousands of millions, it may eventually reach much larger amounts. The Western European support for improving reactor safety in Eastern Europe amounts to at least 1300 mill. so far (200 mill. from Germany). The PHARE and TACIS programs of the European Union represent 500 mill., bilateral western projects total 1200 mill. [8].

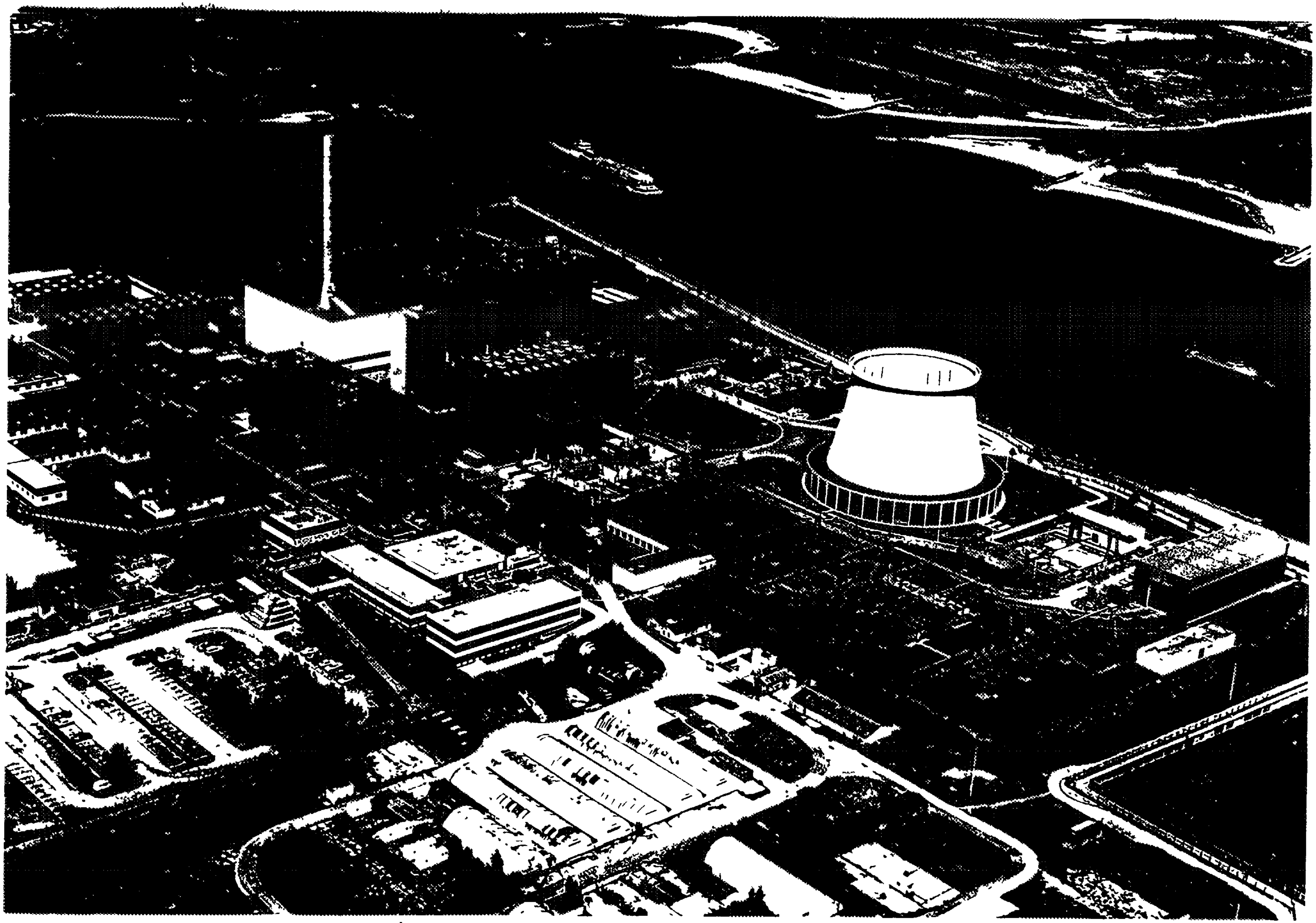
Many of the listed effects have been much less evident in more "pragmatic" countries such as France, than in more "fundamentalist" countries in Northern and Central Europe. There have also been numerous less serious but interesting side-effects following the Chernobyl accident, such as

- official limits for I-131 in milk of 20 Bq/l in the German state of Hessen (which amounted then to 1/180 th of the internationally recommended value, and to one fifth of the milk's natural K-40-activity),
- different grazing permits for cattle in the French and Dutch speaking parts of Belgium, thus making the language line (probably for the first and last time) visible by satellite,
- the refusal of valuable high-protein food gifts from the EU in Bangladesh [6], and
- problems in the export of European agricultural products, construction steel, etc., to "less contaminated" countries.

Thus, on a basis of monetary units per gram, Chernobyl fall-out became (with the possible exception of same microbes causing large epidemics and exotic transuranic elements produced in accelerators) probably the most expensive substance ever in European history.

Among the more important reasons for the dramatic distortions in the perception of the Chernobyl consequences, compared to these of other natural or man-made recent events causing a larger number of casualties (such as the sinking of the Estonia, the Bhopal chemical accident, or the Baku subway fire) are

- a most unfortunate information (initially non-information) policy by the Soviet Union after the accident, leading to much unnecessary speculation, confusion, and anxiety,
- overconservative, often politically motivated radiation protection recommendations, regulations, and concepts such as "collective dose", leading to high numbers of hypothetical cancer deaths and decisions to interdict sheep and reindeer in Norway based on calculations of a collective dose of one man-Sv thus saved at a cost of 170.000 and 57.000 $, respectively (assuming a "price" of 100.000 $ per man-Sv) [7], etc.,



- economical interests of the "radiation protection industry" (such as instrument manufacturers, monitoring services, decontamination and remediation companies, safety consultants, and radiation effects research institutions) resulting in an overemphasis on radiation hazards compared to other civilisatory risks,
- overrepresentation in the media of a small number of ideologically motivated antinuclear activists, promoted by journalists lacking scientific education and frequently with a tendency towards unqualified sensationalism for obvious commercial reasons,
- a tendency among many individuals and institutions (including governmental agencies) in Ukrainia, Byeloruss and Russia to exaggerate Chernobyl effects, as well as potential future risks, in order to attract more attention and support during a difficult economic period, as well as
- a "Zeitgeist" in some Western countries characterized by a very sceptical attitude towards science and technology in general, which is considered more fashionable among many "intellectuals" and public opinion multiplicators than the understanding of scientific, technical and economic facts.

The situation was complicated by additional psychological factors such as a deep-rooted distrust in governmental announcements in some countries. Concerning the widely discussed question of eating fresh vegetables etc., in France Prof. F. Pellerin, director of the national radiation protection service, explained on national T.V. that there are no health risks involved, and almost everybody in France believed it and acted accordingly. When the responsible German Minister of the Interiour Dr. Zimmermann said the same on German T.V., very few viewers believed it, and almost nobody bought produce (in particular mushrooms and fresh berries), children were not permitted to play in sandboxes, etc.. Similar effects have been reported in other countries. For example, the director of the Norwegion Health Directorate announced on April 30, 1986, on national T.V. that "we can guarantee that there is no reason to make any changes in habits", but many people preferred to believe Swedish warnings in the media against drinking water from certain sources, etc. [9].

The change from the old Curie activity units to the numerically much more frightening Becquerels contributed further to radiophobia and confusion. One of the author's experiences may illustrate this point: When he explained in a senior staff meeting shortly after the accident that most of the public concerns were caused by the Curie-Becquerel-transition, the director of the German Standards Institute remarked with a smile: "A splendid idea. We will pay our staff in the future in Italian Lira." Remembering the days after Chernobyl also had its lighter moments, such as an inquiry of a hospitalized old lady how dangerous her bedside flowers are...

However, unfortunately what initially appeared to be just "an accident in the head" for many Western Europeans during the last decade, turned out to result in rather serious effects not of a radiological, but of a political and economic nature: Direct and indirect "costs" in Western Europe may eventually far exceed the 100.000 million dollar mark. The permanent loss of many jobs not only in the nuclear industry, higher taxes and energy prices, and reduced chances of technical and economic progress remain important long-term consequences of Chernobyl in large parts of Western Europe.

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Note: The author acknowledges encouragement and many valuable comments from colleagues, but the paper basically reflects the author's data compilation, not the "official opinion" of any institution with which he is associated.

XA9745888

GERMAN MEASUREMENTS OF THE POPULATION DOSE AROUND CHERNOBYL

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1. Introduction

The reports on the consequences of the reactor accident at Chernobyl in late April 1986 have been extremely contradictory as yet. In the post-Soviet republics affected by the accident there was a general lack of reliable information concerning the levels of radioactive contamination of the environment and of foodstuffs. Where data were given, they were insufficiently supported and explained.

Not least, these circumstances led to considerable disquiet and concern amongst the public even at a great distance from the site of the accident. In order to assist in informing those affected and above all to determine their actual radiation exposure, the Federal Republic of Germany performed a measuring campaign in the three post-Soviet republics between Moscow and Kiev in the years 1991-1993. For this purpose, the Federal Ministry of the Environment made available funds of about DM 12 million.

Starting in 1991 a total of 22 vehicles with 27 measuring assemblies and more than 150 staff, recruited on a voluntary basis from various institutions in the Federal Republic of Germany, were engaged in the first measuring campaign lasting from mid-May to early October 1991 (1). In the following two years the programme was slightly reduced.

Great store was set by the comprehensive information of the population. In addition to general information through the media two leaflets were distributed to all visitors to explain the radiological situation. Each person undergoing measurements or bringing food samples received a form with the results and a short explanation in Russian. This was favourably accepted by the public.

2. Environmental Measurements

In each settlement the measuring programme began by determining the area dose rate and the soil contamination. Subsequently, basic foodstuffs, such as water, milk, meat, potatoes, bread and cereals, were examined by gamma spectrometry as an aid to interpreting the whole-body measurements. All foodstuff supplied by the public was measured. Each participant was given the contamination result measured for his food sample and a brief explanation in Russian on a specially designed form.

A total of more than 4000 food measurements, more than 500 soil examinations and more than 1000 area dose rate determinations were carried out.

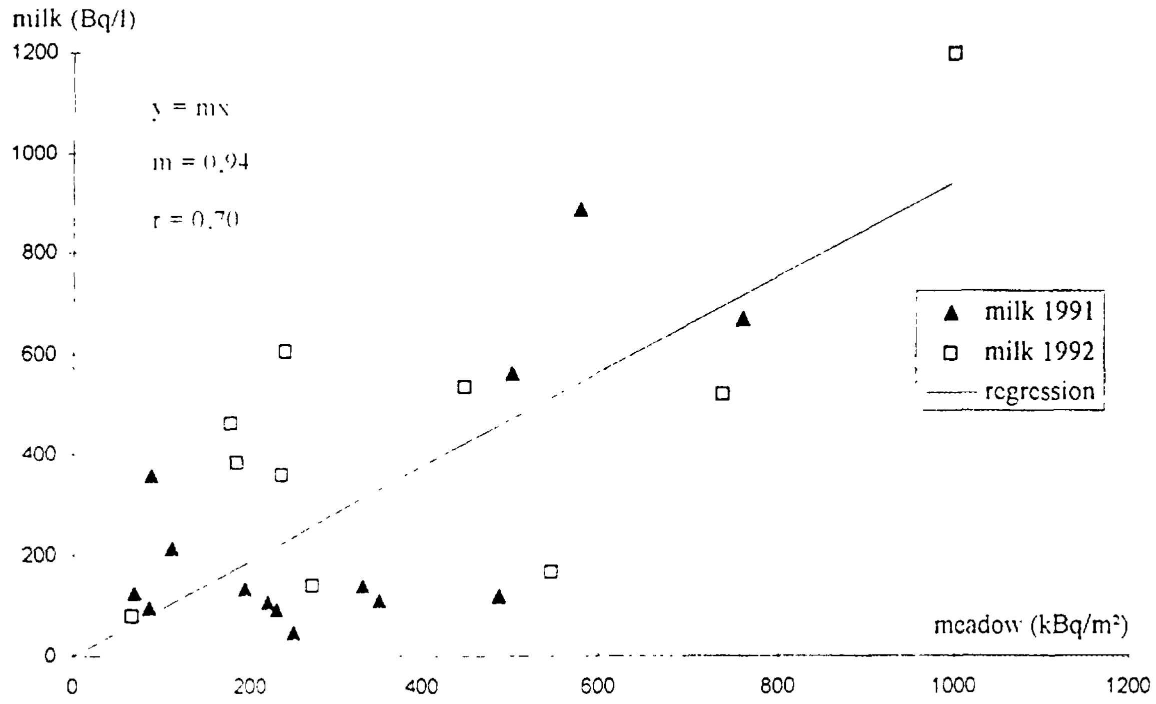

Fig. 1 : Relation between Cs contamination in milk and soil contamination on meadows in 1991 and 1992

The strong relation between the cesium ground contamination and the area dose rate is confirmed by our measurements. The gradient of the correlation line for undisturbed ground (pastures) corresponds to a dose rate-ground contamination relationship of about 1.1 µSv/h for 1000 kBq/m^2 of Cs contamination on soil. For arable land (fields) it is 0.5 µSv/h.

In 1991 the average milk concentration east of Novosybkov in the Klincy district was about 130 Bq/kg, on the basis of 227 milk samples from private farms. But maximum values were still high, the highest was 3700 Bq/kg. In this district, the official limit of 370 Bq/kg was exceeded for 25% of all results.

A correlation was found between the milk concentration and soil contamination of pastures. The milk concentration in relation to the contamination of pastures for the years 1991 and 1992 is given in fig. 1 The correlation is weak but evident. In 1993 the correlation could not be confirmed.

3. Incorporation Measurements

Three semitrailers with 4 measuring assemblies each and up to 4 box-type delivery vans with 2 measuring assemblies each were employed for the whole-body measurements. This permitted flexible operation. The delivery vans enabled measurements to be carried out at small settlements and the semitrailers were parked in towns or large villages where they remained stationary for a few weeks thus permitting a high throughput.

It was to be expected the detectable incorporation of the population would only consist of the gamma-emitters Cs-137 and Cs-134. Even in 1990 other international projects, especially the

IAEA project, could only find these radionuclides in human bodies. On the basis of the environmental and food measurements, a significant contamination of the population with Sr-90 and Pu-239 was finally ruled out.

Therefore, an important criterion for selecting the measuring systems was a sufficient detection sensitivity for the isotopes Cs-137 and Cs-134 in a short measuring time appropriate for the measuring task. It should be possible to detect a Cs activity of 1 kBq in the human body within a measuring time of 1 minute. This requirement was fulfilled not only by spectroscopic, nuclide-resolving measuring systems but also by simpler systems with plastic scintillators. This mixed system permitted mobility and cost savings since the instruments operating radiometrically were much lighter and considerably cheaper.

For intercalibration purposes, comparative measurements were carried out each year with a whole-body phantom made available by our Russian partners from the Scientific Research Institute for Hygiene at Sea of the Ministry of Health of the former USSR.

Measurements were carried out in more than 240 settlements in the ten regions of Bryansk, Kaluga, Orel, Tula in Russia, Gomel, Mogilev, Brest in Belarus and Kiev, Shitomir, Rovno in Ukraine.

All measured data were evaluated according to three categories. The breakdown of these categories can be seen from table 1. A differentiation was made between adults and children. The limits for children were selected in such a way that for 5- to 12-year-olds the respective dose corresponds to the limits for adults. For babies a special counter was developed and put into operation in 1992. For this group the limits were reduced once more.

Table 1: Division of the measured data into categories

	adults	children
category 1	up to 7 kBq	up to 4 kBq
category 2	7 kBq to 25 kBq	4 kBq to 15 kBq
category 3	over 25 kBq	over 15 kBq

The limit of 7 kBq actually results in an effective dose of 0.3 mSv/a and the activity of 25 kBq leads to an effective dose of 1 mSv/a. Measurement results in the first category do not give any cause for concern. Body activities within the second category are also sufficiently safe, but in this case it was recommended to limit the intake of food known to be highly contaminated (e.g. mushrooms, game). The values in the third category do not in any case exceed the permissible limits of intake according to ICRP 30. The highest measured result was 770 kBq. For continuous uptake of Cs-137 the annual dose limit of 50 mSv/a corresponds to a body burden of more than 1000 kBq.

A summary of all body counter measurements carried out by German experts from 1991 to 1993 is given in table 2. A total of 317,011 measurements were performed in the three republics Russia, Belarus and Ukraine. The total number of measurements decreased from 163,000 in 1991, to 90,000 in 1992 and 64,000 in 1993 due to our continuously reduced funding and a reduction in the

Table 2: Summary of all German body counter measurements 1991-1993

	number	cat.1	cat.2	cat.3
1991				
Total Russia	163 033	93.7 %	5.3 %	1.0 %
1992				
Total	90 460	90.6 %	7.9 %	1.5 %
Russia	49 858	85.8 %	11.7 %	2.5 %
Ukraine (Fastov)	11 373	100 %	0 %	0 %
Belarus	29 229	95.2 %	4.4 %	0.4 %
1993				
Total	63 518	81.0 %	14.6 %	4.5 %
Russia	14 836	70.0 %	22.9 %	7.1 %
Ukraine	36 126	84.5 %	11.9 %	3.7 %
(incl.Rovno)	2 773	38.6 %	34.9 %	26.5 %)
Belarus	12 556	83.8 %	12.4 %	3.8 %
1991-1993				
Total	317 011	90.3 %	7.9 %	1.8 %

interest of people who in the previous year had been found to have low exposure. Nearly 90 % of all results are within the lowest category 1, about 8 % are in category 2 and only 2 % must be assigned to category 3.

Some particularities can be observed for the different republics and for different years. Thus, the category 3 fraction increased over the 3 years from 1 % to 1.5 % and 4.5 %, probably due to the reduced interest of people with low exposure in a repetition of their measurements.

The highest fraction of category 3 results was found in 1993 in the district of Rovno where 26.5 % had to be assigned to the highest category. In Rovno in the western part of the Ukraine the ground contamination is not high. Thus, the high body burden in these inundated areas demonstrates the overriding importance of transfer factors.

4. Measurements of the external Dose

In 1992 and 1993 the measuring programme was supplemented and completed by personal dose measurements of the external dose. They were performed in collaboration with colleagues from the Novosybkov branch of the Institute for Radiation Hygiene in St. Petersburg. The personal dose was mainly measured in Russia near the western border of the Bryansk region in the districts Novosybkov, Slinka, Klimovo, Krasnaya Gora, Gordeyevka, Klincy and Starodub. In 1992 a minor part of these measurements (about 10 %) was done in the Gomel Region in Belarus in the districts Narovlya, Dobrush, Chechersk and Korma.

Personal dose measurements were carried out in about 100 selected settlements with varying Cs ground contamination from less than 74 kBq/m^2 to about 3700 kBq/m^2. In some of these settlements decontamination measures had been previously taken. The settlements also varied due to size and economy (agricultural, industrial).

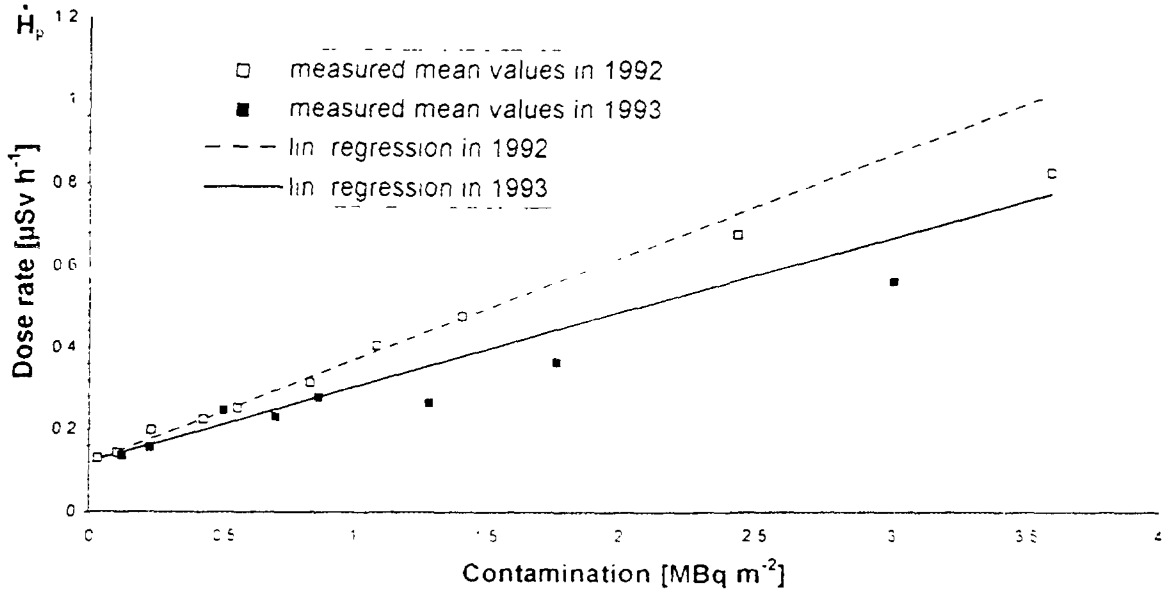

Fig. 2 Correlation between the person-related dose rate $\dot{H}_p$ and the soil contamination in villages

The dosemeter was a tissue equivalent LiF thermoluminescence detector of the type TLD-100. The dosemeter was distributed together with an information sheet and a questionnaire for statistical reasons.

The measurement of the personal dose was carried out in summer 1992 and 1993 between May and September. A supplementary measuring campaign took place in winter 1993/94. In 1993 every person being monitored received a second dosemeter to determine the area dose rate in their home.

Figure 2 shows the correlation between person-related dose rate and soil contamination for the 1992 and 1993 measurements. The deviation of the values for high soil contamination is to be attributed to decontamination measures since the contamination values specified apply to the original contamination prior to decontamination.

These regression lines allow an estimate of the personal dose equivalents.

The effective dose equivalents estimated are compiled in table 3 for a soil contamination of 1 kBq/m^2. The contribution from natural radiation exposure was not taken into consideration. The effective dose equivalent in lines 1 and 2 was calculated from measured area dose rates under consideration of shielding and staytime factors inside houses. The effective dose equivalent in line 3 is calculated from the soil activity according to the official method of the State Committee for Hydrometeorology in Russia with a derived area dose factor ADF = 0.13 $mSv \cdot km^2 \cdot Ci^{-1} \cdot a^{-1}$. Line 4 is based on personal dose measurements by the Institute of Radiation Hygiene, St. Petersburg (2), and the effective dose equivalents in lines 5 and 6 are derived from fig. 2.

As was to be expected, there is not complete agreement between the effective doses calculated according to the different methods. The values derived from the area dose rate are higher than those from personal dose measurements. It should be noted that the calculation of the effective

Table 3: Comparison of effective dose equivalent determined according to different methods for a soil contamination of 1 $kBq \cdot m^{-2}$

line	method	year	H µSv/a
A	**from the area dose rate**		
1	assuming 0.92 $\mu Gy \cdot h^{-1} \cdot MBq^{-1} \cdot m^2$ from [2]	1991	2.52
2	German measurements over pasture (1.1 $\mu Sv\ h^{-1} \cdot MBq^{-1} \cdot m^2$)	1992	2.66
B	**from soil contamination**		
3	official method of the State Committee for Hydrometeorology	1991	3.51
C	**from individual dose measurements**		
4	Institute of Radiation Hygiene	1991	2.10
5	TLD for villages (German measurements)	1992	1.62
6	TLD for villages (German measurements)	1993	1.34
7	TLD for towns (German measurements)	1992	0.77

dose from the area dose rate was based on some very generalized assumptions. The values derived from personal dose measurements should be most reliable since they take precise account of the presence of persons at differently contaminated locations.

5. Dose Assessment

Actual dose:

The dosimetric evaluation of the measurements is given in tab. 4 for the villages with the highest average body activity in1993. On the assumption that the cesium body burden is constant over the whole year, an ingestion dose factor of 0.04 mSv/kBq·a for adults >20 a applies.

Further, tab. 4 presents the results of the external dose calculation for the mean soil contamination of each village. According to tab. 3 the calculation of the external dose equivalent from soil contamination was performed applying the area dose factors measured by TLD measurements.

The highest current total doses were found in Kirov in the Narovlya district. This is a settlement near to the forest with a high degree of self-sufficiency. In the Rovno region internal doses are high and the external doses are low because soil contaminations are low.

The ICRP dose limit for the general population of 1 mSv/a is exceeded in most of the villages given in tab. 4, but in no case the dose limit for translocation (5 m Sv/a) was reached. All results are given for adults. For children the doses are in the same range, because, in general, they had significantly lower contamination. This compensates the higher biological sensitivity.

Dose reconstruction:

The external dose reconstruction makes use of the fact that the decrease in the dose rate of the Cs-137/Cs-134 mixture due to the physical decay, considering the higher area dose factor for Cs-134, for a 10 a period since 1986 is about 65 %; 18 % in the first year, 4 % in the tenth. In addition, migration effects must be considered. Our measurements in 1992 over undisturbed ground yielded a mean value of 0.69 nGy/h over soil contaminated with 1 kBq/m^2 Cs-137. This is a reduction of 63 % compared with the 1986 value of 1.82 nGy/h given by Russian scientists (2). Thus, migration effects are in the same order of magnitude as physical decay. For our calculation we considered all these effects with the consequence that an annual dose in 1993 resulted in an 18 times higher 10 a dose.

The reconstruction of the 10 a-internal dose on the basis of our whole body counter measurements needs some knowledge about the development of the activity level in humans during the first few years after the accident. Results from Russia and Belarus (3) reveal a decrease by a factor of 10 from 1986 to 1991. But unfortunately, this information is not very sure due to the fact that the measurements were not carried out systematically over the years always with the same persons. Therefore, the variation for these results is great.

Systematic monitoring of a fixed group of persons over the first few years after the accident was performed in Germany. After an initial increase in 1986, an exponential decrease was observed since 1987 with a factor of about 20 for the first 5 years (1991). Considering the fact that the contamination and the life style in rural German areas like Berchtesgarden seems to be more similar to urbanized Russian areas, we suggest for dose reconstruction purposes for towns in the CIS a decrease by a factor of 20 from the end of 1986 to 1991. For villages we suggest a decrease by a factor of 15 from the maximum at the end of 1986 to 1991, being between the German and the Belarussian experience.

Tab. 4: Annual dose 1993 and 10-year doses for adults in settlements with the highest body activities measured in 1991-1993

village	district	int. dose [mSv/a]	ext. dose [mSv/a]	10 a int. dose mSv	10 a ext. dose mSv	10 a total dose, mSv
Cheremel	Rovno	2.3	0.1	104	1	105
Veshiza	Rovno	2.2	0.1	92	1	93
Kirov	Gomel	2.2	1.9	90	34	124
Staroye Selo	Rovno	1.8	0.1	72	1	73
Drosdyn	Rovno	1.7	0.1	70	1	71
Unecha	Klincy	1.3	0.7	51	11	62
Veprin	Klincy	1.5	1.3	62	21	83
Beresovka	Klincy	1.3	0.3	53	5	58
Sarechye	Klincy	1.3	0.5	53	9	62
Tulukovchina	Klincy	1.1	0.5	46	10	56
Uvelye	Krasnaya Gora	1.1	0.6	46	29	75
Verbovka	Rovno	1.0	0.1	41	1	42
Saborye	Krasnaya Gora	1.0	3.1	41	56	97

In tab 4 the results of the ten-year dose equivalent for the external and internal doses are listed for those villages and towns of the three republics which had the highest mean body activities The highest 10 a total dose is 124 mSv This value does not represent any acute health risk and is below the ICRP dose limits for persons professionally exposed to radiation

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PUBLIC ACCEPTANCE AND ASSESSMENT OF COUNTERMEASURES AFTER THE CHERNOBYL ACCIDENT

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General Background. Previous studies confirmed that the main reason of the psychological stress after Chernobyl was a worry about radiation influence on personal health and health of children [1,2.3]. This "Chernobyl stress" is typical "information" or emotional stress resulting from mass media information on radioactive contamination and exposure but not from direct personal visual or auditory and other impression for 5 million population. The population was not able to define the radiation danger by direct sensual perception without measuring equipment but was obliged to change their life-style and diet as a remedial action and to follow the radiation protection requirements and advices.

Therefore the anxiety was related not only to information about the accident but also to implemental countermeasures, which changed the everyday life. The countermeasures became the first real sign of the accident.

Methods. In 1988-1994 studies based on population interview of about 5 thousand residents and questionnaires were carried out on contaminated (15 - 40 Ci/km2) territories, adjacent and distant areas. The following information was used:

- population knowledge of protective measures;
- sources of information about radiation and level of trust;
- assessment of the effectiveness and reasons of non-satisfaction of the protection measures;
- compliance and involvement of population in countermeasures including effects of life-style changes and behavior;
- public opinion on priority for financial expenditure for mitigation of accident consequences.

Results

Questionnaire contains the list of 25 types of protective measures. The main ones were the radionuclide control of food, decontamination of areas and structures, improvement of the food stuffs quality, improvement of medical services, improvement of conditions of life and economic support.

The study of public information indicated, that population has no complete knowledge on the protective measures implementation and their effectiveness. In 1992, 75 - 95% respondents knew about decontamination, repairment of roads, medical supervision; 35 - 58% of them were informed of dosimetry control, use of special facilities; only 26% persons knew about other protective measures. Surprisingly only 27% knew about the limitation and prohibition of private land use and food production introduced during first months after the accident.

Table I. Public Awareness of Protective Actions.

Action	Relative (%) number respondents contaminated areas		control areas	
	1988	1992	1988	1992
Correct:				
- cleaning of dress and shoes	96.7	26.4	97.6	17.6
- frequent washing	95.1	26.4	92.3	17.6
- closing windows and doors	78.6	43.9	87.2	46.4
- stable iodine profilaxis	43.2	20.0	59.4	22.4
Noncorrect:				
- frequent outdoors walk	35.7	6.0	31.2	4.8
- extensive home ventilation	34.9	6.0	34.8	4.8
- alcohol drinking	18.3	16.0	23.1	18.8

At present public knowledge of consequent compliance with the countermeasures and prohibition diminished (Table.I) except the limit of the time of out-door staying.

In 1988 (Table II) population complied with such protective measures, as the change of nutrition. Half of the respondents improved their diet. In comparison with the above mentioned data the new results indicate that more respondents (55%) have noted the improvement of economic situation. Improvement of meal quality observed only 13% interrogated on contaminated territories. Nutrition changes after the 1986 remained for many years, and in 1993 this fact was stated by 10% of the respondents even from the remote clean areas.

The results of the survey in 1988-1994 show constantly, that the population in contaminated areas had changed the lifestyle. It is mentioned above, that the 23 - 33% of the population started to stay and work more often at home, 36 - 50% were separated from relatives and friends. Separation from close friends and relatives is one of the important negative consequences of the Chernobyl accident.

Table II. Public Assesment of Compliance with Protective Measures at the Contaminated Areas

Answers	Relative (%) of respondents	
	1988	1992-93
Better meal	57	13
Better economic situation	36	55
More often stay at home	33	23
Have their vacations in other locations	46	41

In 1992 definite positive or negative evaluation of protective measures (Table III) was given by the equal number of interviewed. Contradictory, at the same time the positive evaluation by the respondents was given to such particular measures, as exception of contaminated products (72% questioned), systematic radionuclide control, repairment of the roads, relocation, decontamination of the territories, medical services (from 32 to 47% of respondents).

Table III. Public Evaluation of Countermeasures at Contaminated Area in 1992.

Evaluation	Relative (%) number of respondents	
	activities of scientists and specialists	protective actions
Negative	24.9	41.0
Positive	25.6	40.7
Don't know	49.5	19.8

Later in 1994 each third respondent at contaminated territories noted the importance of radiological control of food; approximately the same number of interrogated considered, that the measurements had not any sense; other have preferred not to know about measurements of agricultural alimentary products, though during interviews dosimetry was permanently performed.

In 1994 the regulatory dosimetry control, obviously protective measure, was not percepted by population as an obligatory and effective and only every 3-rd respondent from contaminated area considered that radiometric control of food provide "very substantial" or "substantial" benefit. This is true also for removal of private stock which was not considered by population as a positive protective measure. Probably this action was a tragic symbol of "substantial" benefit. This is true also for removal of private stock which was not considered by population as a positive protective measure. Probably this action was a tragic symbol of an accident situation.

In 1992, 22% of the respondents considered the payments of "compensation" as a cause of anxiety. The contamination of territories, special medical and radiological control increased the anxiety in 9-11% of interviewed. Public distress by relocation for all groups was 55%.

Contradiction in assessment of protective measures was expressed by the fact that in answers to doubling questions no one from respondents was in favor of cessation of protective countermeasures.

In 1993 the absolute majority of respondents from the restricted and non restricted areas did not feel themselves and their family protected from radiation in a case of another nuclear accident.

Table IV. Public Assesment of financial expenditures in 1993

Money should be used for:	Relative (%) respondents	
	contaminated area	control area
direct payment	52.8	29.2
decontamination	48.0	71.2
new house-building	37.2	31.6
social rehabilitation	20.8	40.8
community services development	21.2	12.4

In 1993 (Table IV) population on contaminated territories evaluated Chernobyl money fairly cash and decontamination of territories as the highly important protective measures (half of all interrogated on contaminated territories). The population considers financial compensation as one of the most important measures. As a social rehabilitation measure the improvement of health care is considered to be the first priority. All interrogated persons (98%) on contaminated territories in 1993 have noted lack of improvement of medical services during the last year.

Conclusions.

1. The different perception of various countermeasures was noticed. The population positively accepts decontamination, improvement of medical care, financial compensation and some other measures. The change of a lifestyle, limitations of private householding and land use are main consequences negative rated.

2. Contradictory evaluation of countermeasures result from misunderstanding of their aims and partly from psychological perception of remedial action as a "symbol" of a hazard in everyday life.

3. With time the public forget some protective measures and would not be able to use it in future.

4. Therefore no significant positive changes of psychological and emotional tension could be expected resulting from protective and rehabilitation actions for limitation of radiation exposure without some special measures of psychological support.

5. Countermeasures effectiveness definitely depends on their psychological "acceptance" by population and active public participation. Promotion of these activities requires:

- further development of special public education programs on countermeasures aim and significance,
- definition of priority measures for population benefits (t.g. improvement of health care),
- promotion of mutual understanding, actions and trust of public, experts and administration.

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CONCEPT OF RADIOLOGICAL, MEDICAL AND SOCIAL PROTECTION OF THE POPULATION OF RUSSIA AFFECTED BY ACCIDENTAL EXPOSURE

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Main principles of population radiation protection fromvarious accidental exposure, including the Chernobyl accident, have been implemented in officially approved Concept "On radiological, medical, social protection and rehabilitation of the Russian Federation population affected by accidental radiation exposure". The concept includes basic principles of radiation protection, designation of regional radionuclide contaminated territories, records and registers of exposed persons, health protection and rehabilitation, socio-economic and legal aspects.

The main task for scientists and administration in the field of health and sociology, economy and law is limitation of population harm , rehabilitation and compensation for risk and detriment at early and late stages of radiation accident. This approach is implemented in the recent Concept of radiological, medical, socio-economical and legal protection of population subjected to accidental exposure, and requirements for measures at late stage mitigation of radiation accident, accepted by Russian National Commission on Radiation Protection. The Concept is related to all major Russian radiation accidents: the Urals, Chernobyl and similar to them, such as Altai situation, with the following revision of present legislation. Earlier a Concept on rehabilitation and protection measures has been accepted in 1993

The basic principles of this Concept present the main directions of population protection and rehabilitation.The Concept considers that in condition of practically "completed" after-accidental exposure (term used for radiation accidents and late effects of nuclear tests jointly) only the following measures to reduce population exposure are practically possible, such as justified decrease of medical exposure and exposure to radon and progeny in the houses. The introduction of such measures is actual and possible, because radiation from medical exposure and natural level of radon in the houses is rather substantial in the affected areas and higher than average Russsian levels. The dose reduction in medicine is achieved by substantial limitation of reglamentary examinations (reduced for last years), high frequency of X-ray - fluorography, with use of all technical means for dose reduction, but with necessary quality and quantity of diagnostic information. Optimization of such examinations could in the near future reduce the population collective dose not less than for 30 %. Of course, the higher reduction can be achieved by replacement of obsolete X-rays units for modern equipment. Experience with the reduction of diagnostic medical exposure in Bryansk region affected by the Chernobyl accident showed a possibility to decrease a collective diagnostic dose for one order of magnitude, without loss of necessary quality and quantity of diagnostic information.

Other possibility to decrease the population exposure is to reduce the radon contents in the houses. The territories with high level of radon emanation from soil and concentration in the houses exist, especially in the Altai area. Most of the houses have no radon protection. Radiohygienic inspection of the houses should be introduced with radiation control of projects and building process of the houses, the existing houses should be equipped with radon protective systems. Reduction of such exposure cannot completely compensate the post accidental overexposure, but can limit radiation effects in progeny. The proposed radiation protection measures should be introduced on the basis of socio-ethic considerations, priority should be given to the areas with extensive exposure of population in the past.For the assessment of present level of population radiation situation and effectiveness of protective countermeasures , a precise system of population dose assessment from basic radiation sources should be established in all affected areas.

The Concept introduces a legal definition of the radiation "exposed" and "suffered" to assure adequate radiological, health and social protection of population after accidental exposure. First of all, the Concept "the exposed" defines a person who has received acute radiation exposure with dose more than 5 Sv (50 mGy). As a criteria limit, excessive occupational annual dose limit is used. Higher than 25 cSv (250 mSv) dose is an accidental level which gives the basis to include such person into the group of high risk and requires a special medical care. Selected limits have a radiological basis, as well as social foundation.

"The suffered" defines a person with the established radiation injury and other radiation effects and illness for which the casual radiations with accidental exposure are established.

Population dose as a result of nuclear weapon tests is estimated by the State Russian Committee on Sanitary and Epidemiological Surveillance and assessment of health and disability causation data performed by the Ministry of Health special experts councils on basis of special instructions.

Data on all persons affected by radiation with dose more than 250 mGy should be recorded at radiological and epidemiological register, including also:

1. children born after intrauterine exposure with more than 50 mSv;
2. adults with thyroid absorbed dose more than 1.5 Gy and children with more than 0.75 Gy;
3. children born after accidental exposure of a person included in the register.

For persons who are selected by expert councils as "the affected", the dose reconstruction should be performed. For health protection and rehabilitation of persons included in radiation epidemiological register, a special medical examination should be provided in accordance with the program approved by the Ministry of Health, and other exposed persons have a possibility of annual health examination to diagnose premorbidity state,latent pathology and early diagnosis of illness for timely prevention, therapeutic and rehabilitation medical care.

Special medical teams of qualified specialists are organized for medical supervision of the exposed and affected persons. Guidelines for medical examinations and selection of a group of high risk are envisaged. Medical care of the affected and ill persons and their health rehabilitation is provided at varous medical establishments, including rehabilitation centers. In addition, medical care includes the measures to increase general fitness and anticarcinogenic protection of the irradiated persons and progeny. At present new special highly effective anticarcinogenic products have been developed in Russia for the prevention of cancer, not only as drugs, but also as special food additives reducing by one order a probability of cancer induction, with increase of life span.

The Concept's recommendation envisaged the priority of medical supply and staffing of health establishments at the area where the majority of affected population is located, and especially improvement of children health care. Preventive measures against harmful environmental chemical and physical fagents have been introduced in the area of high radiation exposure to minimize the health consequences of exposure by public education in health radiation protection and introduction of hygienic habits. Education and information systems are introduced for this purpose. Most difficult but important task task is the promotion of health life style,e.g. limitation of smoking and alcohol use, propaganda of fitness improvements,especially for young generation. All protection and rehabilitation measures should be explained to the public to assure psychological protection of population, to prevent psychoemotional effects. For this reason a system of periodical objective, comprehensible and essentially optimistic public information should be provided with help of qualified radiation protection experts who can overcome noncompetent opinions and rumours of laymen. Publication of booklets, information bulletins and periodicals, lectures on radio and TV should be promoted. Special attention should be given to the increase of knowledge in population groups, such as mass media personnel, administrators, health personnel and teachers who are forming public opinion. Periodical studies of the public opinion and psychological population status should be performed. At present the most complicated problem is socio-economical protection of the exposed population which includes general and individual measures on the basis of qualified expert assessment of the extent of detriment and adequate volume and means of compensation. It is accepted that the exposed and suffered persons have rights to compensation for damage, such as physical and sychological health impairments. This compensation could include financial payments and privileges according to damage extent. The amount and character of compensation should be defined by legal acts of Federal administration with local authorities. The basic criteria for decision-making on the form of compensation and social rehabilitation should be defined by classification of individuals by groups of the suffered and exposed categories.

For the suffered and exposed by doses higher than 250 mGy the individual compensation measures, such as privileges and payments and general social rehabilitation measures are implemented. For lower radiation doses a general system of socio-economical rehabilitation is sufficient which includes priority supply of the affected areas, provision of sanitary and hygienic measures, water supply, adequate system of health and child care. Radiation control of housing and premises is envisaged, paid by the State.

Medical supervision, treatment and rehabilitation of persons exposed to doses higher than 250 mGy also is paid from Federal budget. Provision of adequate law protection of population by all legal services should be assured in the affected areas, and persons have a possibility for free of charge legal consultations and advice on problems related to exposure, provision of necessary documents and information. The publication of legal acts and decrees concerning the exposed population rights in the accessible information sources (local newspapers, radio and TV) is envisaged.

Distribution of the Russian settlements and population according to soil contamination with Cs-137, annual in 1996 and accumulated in 1986-1995 effective dose

Radiological parameter		Number of settlements	Population, thous.pers.
Cs-137 soil contamination	> 0,04 MBq/m^2 (1 Ci/km^2)	**7.600**	**2.600**
	> 0,6 MBq/m^2 (15 Ci/km^2)	**300**	**93**
Effective dose in 1996	> 1 mSv	**200**	**40**
	> 5 mSv	**1 - 5**	**2**
Accumulated effective dose in 1986 - 1995	> 70 mSv	**120**	**25**
	> 350 mSv	**-**	**< 1**

SOCIAL, ECONOMIC, INSTITUTIONAL AND POLITICAL IMPACT IN ROMANIA OF THE CHERNOBYL ACCIDENT

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1. BEFORE CHERNOBYL

The Chernobyl accident has found Romania with a good tradition in the nuclear field that had been founded on a renowned school of nuclear physics and the existence of nuclear centers for research endowed with nuclear reactors and other relevant nuclear installations. Furthermore, the operation of hundreds of nuclear facilities licensed by the Regulatory Authority up to 1961 and the national nuclear power program, this aimed to the commission of five PHWR-CANDU in the eastern part of Romania, on the Danube bank at Cernavoda, provided sufficient conditions for a general comprehension of the nuclear domain problems.

At that time in Romania had been working an inter-ministerial General Head Quarters for intervention in case of nuclear accident and two national surveillance networks, [1], see appendix 1, with 30 years of experience in the monitoring of the environment factors, e.g. air, potable and non-potable water, soil, vegetation, foodstuff as well as the individuals from public. These networks had been promoted, endowed and trained in a preliminary phase by the Institute of Atomic Physics, IAP, that had among its responsibilities that of the promotion of the atomic energy at a national scale. Consequently, on the landscape of Romania there had been known the values of the radioactive content of air, water, soil, vegetation and human body including the influence of Romania's own nuclear facilities to the enhancement of the local radioactive background, [2]. Moreover it had been established a system of procedures for notification that stipulated among the measures taken that of the intensification of the monitoring in case of nuclear emergencies.

As concerns the organizational framework, it is worth to say that at a ministry level had functioned the State Committee for Nuclear Energy which embraces together the coordination and promotion of nuclear energy as well as the regulatory control for the nuclear practices.

2. DURING THE CHERNOBYL ACCIDENT

Because of the data received from the national networks for monitoring of environmental factors, Romanian's authorities started alerting and alarming actions on the 29th of April 1986 when the radioactive cloud reached the Romanian territory from east and north. The General Head Quarters for interventions and an ad-hoc commission analyzed the values and decided to take protective measures. However, the Central State Government adopted the undesirable choice of giving official statements with rather scarce information although it had as available pertinent estimations and sufficient data. For this we have as a witness a synthesis of the radiometric measurements, [3], appendix 2, together with associated estimated consequences that had been submitted to United Nations Scientific Committee on the Effects of Atomic Energy, UNSCEAR, and embodied in its annual reports. The results had been coherent to those reported by the neighbouring countries as well as to the estimations made by other experts.

3. SOCIAL, ECONOMICAL, INSTITUTIONAL AND POLITICAL CONSEQUENCES

The Romanian society, on a whole, had been profoundly impressed by the Chernobyl accident,. this fact has been mainly owed to:

- the values of radioactive contamination on the territory of Romania, these exceeded the local radioactive background considerably;
- the inherent proximity to the place of accident;
- some elliptical and over- estimated official statements spread about trough radio and TV.

There have been strong and various pressures, from the highest state dignitaries to profiteers of the new raised emergency. They claimed for preferential actions concerning protective measures at theirs particular residences or demanding prophylactic substances in unjustified quantities or imperiously asked for being internally monitored at the whole- body counter facilities.

In the last years, grounded on an general democratic surge that embraces all the society, have been established non- governmental organizations with preoccupation aimed to the protection of the environment that promote at the some time impartial as well as constructive opinions on nuclear field impact; among them we mention the Romanian Society for Radiological Protection, [4], that is wholly accepted as having positive impact in our society.

Consequently, in spite of information concerning Chernobyl and Koslodui- Bulgaria, as well as opposition of some foreign factors for the future development of nuclear choice, the Romanian society has been keeping an attitude of acceptance of nuclear power. This position is based on a correct decision of the Romanian officials, focused on the most safety reactor and in any case one with containment. The opinion have been sustained by a wide-spreading reports on the technical and management international visits performed at the site of Cernavoda NPP, among them those of WAMAP, RAPAT and OSART missions as well as some leaders of the most relevant international bodies: the General Manager of the Intentional Agency for Atomic Energy, dr. H. Blix, the General Manger of the Nuclear Energy Agency of the Organization for Economic Co.-operation and Development, dr. K. Uematsu. All these have been leading to sentiments of a general confidence in nuclear power as well as to the acceptance of the international interest for it due to its possible transboundary social, economic, institutional and political effects.

The first power reactor will be commissioned in Romania in 1996, ten years after the Chernobyl accident, with positive social and economic consequences. Our hopes in the domain of nuclear power production are tightly connected with the carrying on work at the second unit at Cernavoda, this is in an advanced level of mounting of the main equipment, and after that the running on the efforts for the 3rd, 4th and 5th units. The existence of an appropriate site accepted by national and international authorities and the presence nearby of a population attached spiritually and economically by this plant, as well as the scarce of power in the neighbouring area, that includes not only Romania, are strong arguments which states pro the future development of Cernavoda NPP.

The main consequences of the Chernobyl accident have been complex:

- there have been important perturbations in the national trade and transport, some countries rejected commodities or turned down perishable goods or delayed transports due to the lacking or even ignoring the international agreements, [5]; it is worth to be noted that the country's reactions were widely different, from some which were fully aware in accepting the goods on the evidence of measurements to some inflexible that rejected transports only because these came somewhere from the direction of Chernobyl;
- there were cases of impossibility of carrying out current operations of importance for national economy, such as the usage of tracers in the petroleum industry.
- there could not be carried out endocrinology analyses because of radioactive compounds of iodine in atmosphere;
- there were compromised some researches that relied on a low background for the environment;
- there were disturbances in some social and economic activities as well as in education and tourism;
- there were significantly losses of foodstuff, especially milk and dairy products;
- it was perturbation in supplying with water.

The Chernobyl lesson emphasized the necessity of reorganizing of the national monitoring network's structure and operation as well as the importance of having specialized organisms for intervention, these must to be involved in-field exercises together with the mobilization of large groups of population in the proximity of Kozlodui NPP, placed at the border between Romania and Bulgaria.

It is important to mention that during the cloud's passage of the national territory and shortly after that, from thousands of amateur photographers nobody reported the degradation, veilance, of the films, so it can be inferred that the external gamma dose did not exceed 0.4 mSv.

However, the expenses for decontamination and the medical attendance, the perturbation of others economic activities will remain still without answer.

An interesting point, in the discussions carried out between the political decedent factors and the technicians, was the cause of the Chernobyl accident in the strange context of an experiment thought to enhance the safety systems in a reactor initially stopped. This exceptional situation, not comprehended then, was generated both by failure of technical systems and, mainly, by unexpected human errors. It must be recognized that from this regretful event each designer, constructor, mounter, operator has reconsidered his conceptions and after that provided additional funds and training for safety purposes. Thus, nuclear safety, or more generally radiation safety, became a priority domain in our nuclear world.

At the institutional level changes have been occurring constantly after 1989 toward legislative and administrative aspects.

The adoption of the new Constitution and its provision that stress out the priority of the international legislation, have created opportunities for the endorsement by the Parliament of nuclear regulations. Thus, on its agenda are under discussions new nuclear laws on the organizational aspects and the promotion of the nuclear field, as well as on the authorities for regulatory and interventions.

On the other hand, as concerns administrative aspects, after the dissolution of the State Committee for Atomic Energy three institutes have been laid down:

- the National Agency for Atomic Energy, NAAE., depending by the Ministry of Research and Technology, that promotes nuclear domain at the national level, [6]; particularly it coordinate researches related to the Chernobyl effects as well as international projects with IAEA, OECD/NEA on the some subject;
- the National Commission for the Control of Nuclear Activities, NCCNA, depending by the Ministry of Waters, Forests and the Environment Protection, connected with the regulations and the control of the nuclear practices;
- the Central commission for the intervention at Nuclear Accident and at the Falling of the Cosmic Objects, CNAFCO, with responsibilities related to intervention at nuclear accidents and at radiological emergencies; this embraces officials from ministries and from NAAE, NCCNA and IAP.

Besides, much more attention is dedicated to local institutes: the sanitary police, for problems concerning radiation, and the police for fighting against illicitly traffic with radioactive substance.

Political leading parties have been sustaining the commissioning of the Cernavoda NPP and the development of the associated activities but all these within the limits of the annually budget. All the platforms of the relevant political parties have provisions that are favorable to nuclear field; however there are stated diverse preoccupation and objectives for the protection and the safety of the industrial installations that have associated risk of accidents.

4. CONCLUSION

1. Romania is among the countries in which took place social, economic, institutional and political effects of the Chernobyl accident;

2. The Romanian society, on a whole, had been profoundly impressed by the Chernobyl accident because of: the values of radioactive contamination on the territory of Romania, the inherent proximity of accident place, some elliptical and over-estimated official statements spread about trough mass-media;

3. There took place perturbations of the economic life, among them: rejection of some commodities and perishable goods, impossibility of carrying out current operations of importance for national economy, compromising of some researches that relied on a low background for the environment, losses of foodstuff, especially milk and dairy products, perturbation in supplying with water.

4. At the institutional level changes have been occurring constantly after 1989 toward both legislative, new nuclear laws are under debates in Parliament, and administrative, separately competent authorities for nuclear energy promotion and regulatory control were laid down, aspects.

5. Radiation protection and nuclear safety culture have reached a satisfactory level for the society and political speeches do not annoy anyone when there are proposing poll taxes for insurance of decommissioning of Cernavoda NPP and transport of radioactive waste activities.

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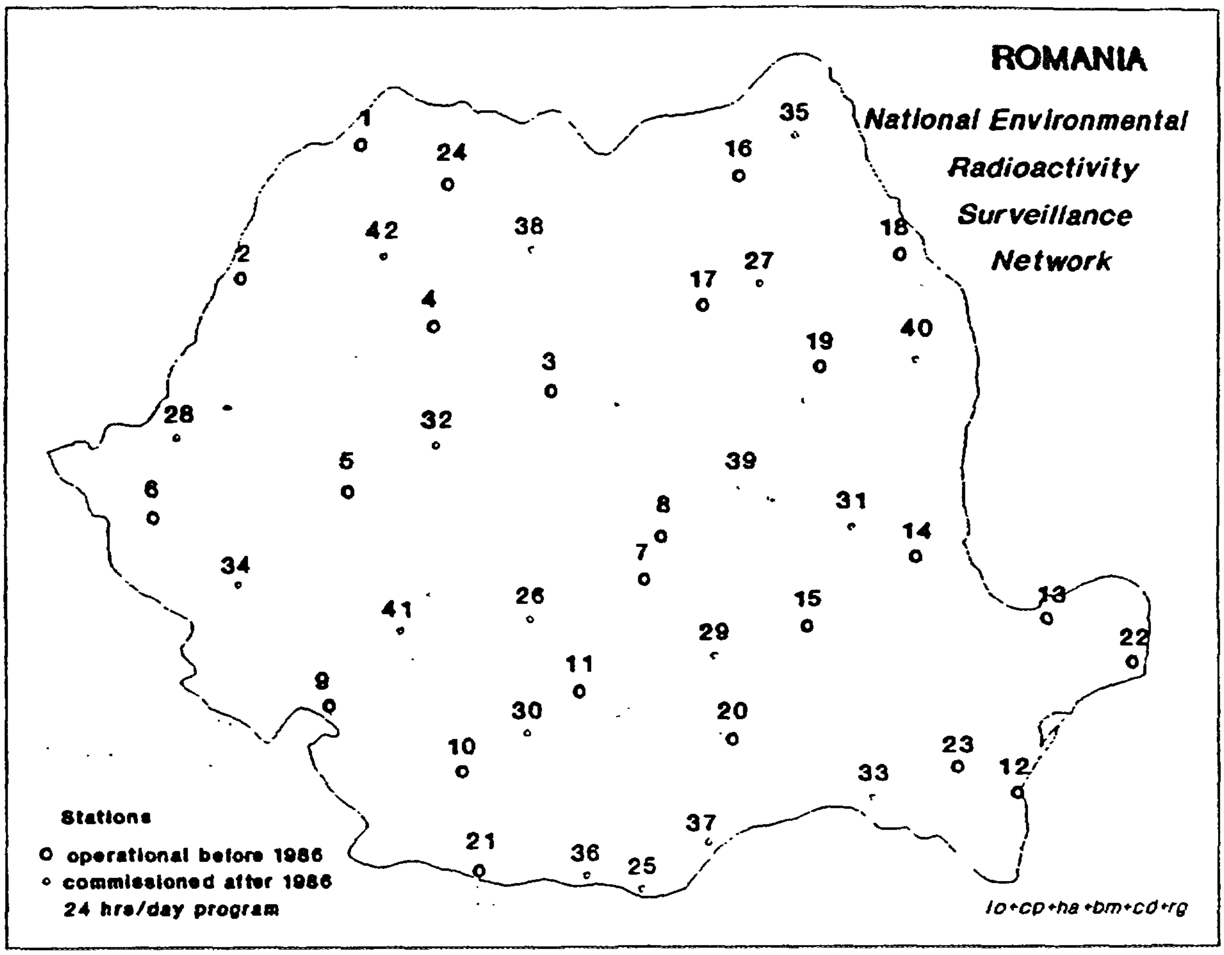
Appendix 1



MINISTRY OF ENVIRONMENT - Environmental Radioactivity Laboratory
Institute of Environmental Research and Engineering

National Environmental Radioactivity Surveillance Network Stations

1 - Satu-Mare	22 - Sf.Gheorghe
2 - Oradea	23 - Cernavoda
3 - Tg.Mures	24 - Baia-Mare
4 - Cluj-Napoca	25 - Zimnicea
5 - Deva	26 - Rm.Vilcea
6 - Timisoara	27 - Piatra-Neamt
7 - Babele	28 - Arad
8 - Brasov	29 - Ploiesti
9 - Drobeta Tr.Severin	30 - Slatina
10 - Craiova	31 - Focsani
11 - Pitesti	32 - Alba-Iulia
12 - Constanta	33 - Calarasi
13 - Tulcea	34 - Resita
14 - Galati	35 - Botosani
15 - Buzau	36 - Tr.Magurele
16 - Suceava	37 - Giurgiu
17 - Toaca	38 - Bistrita
18 - Iasi	39 - Sf.Gheorghe
19 - Bacau	40 - Vaslui
20 - Bucuresti	41 - Tg.Jiu
21 - Bechet	42 - Zalau

Appendix 2

Table I: Radioactive concentrations for the relevant radionuclides in Romania in 1986 after the Chernobyl accident, values are given in Bq/l or Bq/Kg

Radionuclide in the specific product	may	june	july	august	september	octomber	november	december
I - 131								
-milk	700	40	5	-	-	-	-	-
-dairy products	1800	400	50	-	-	-	-	-
-vegetables and fresh fruits	400	50	10	-	-	-	-	-
Cs -137								
-milk	200	80	40	20	18	15	10	5
-dairy products	200	100	70	60	50	30	20	10
-vegetables and fresh	100	50	30	25	20	15	10	5
fruits	300	200	100	90	85	80	70	50
-meat	-	10	70	70	70	70	70	70
-bread								
Cs -134	half of the values for Cs - 137							
I -132 and Te -132	only 1/30 from the values for I -131 in may							
Sr -90								
-milk	6	-	-	-	-	-	-	-
-dairy products	80	-	-	-	-	-	-	-
- meat	2	-	-	-	-	-	-	-

Table II Intake of radionuclides through ingestion after the Chernobyl accident, 1986, [Bq]

Radionuclide	may	june	july	august	september	octomber	november	december
I - 131	25,000	3,000	500	-	-	-	-	-
Cs - 137	7,700	4,000	2,800	2,300	2,000	1,800	1,300	600
Cs - 134	3,850	2,000	1,400	1,150	1,000	900	600	300
Te - 132	800	-	-	-	-	-	-	-
Sr - 90	400	-	-	-	-	-	-	-

Table III Committed Effective Dose corresponding to the above values, [mSv]

Radionuclide	may	june	july	august	september	octomber	november	december
I - 131	1,250	150	30	-	-	-	-	-
Cs- 137	100	50	40	30	30	20	10	10
Cs - 134	70	30	20	20	20	10	5	5
Te- 132	10	-	-	-	-	-	-	-
Sr -90	20	-	-	-	-	-	-	-
TOTAL	1,450	240	90	50	50	30	15	15

Figure 1 Equivalent dose in thyroid, adult, via inhalation, mSv.

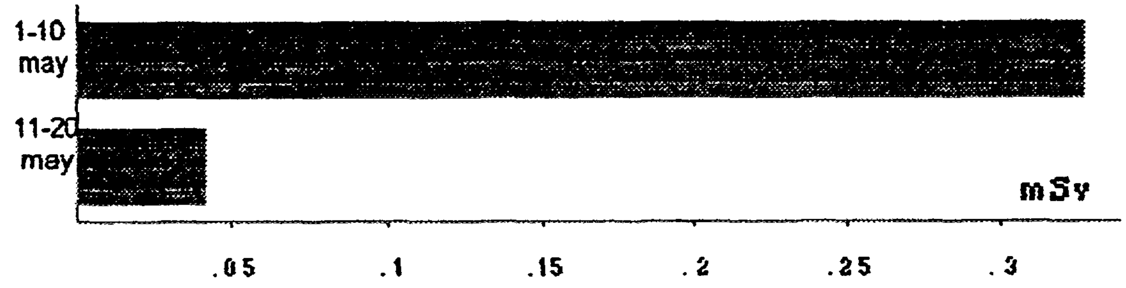


Figure 2 Equivalent dose in thyroid, adult, due to ingestion of dairy products, mSv .

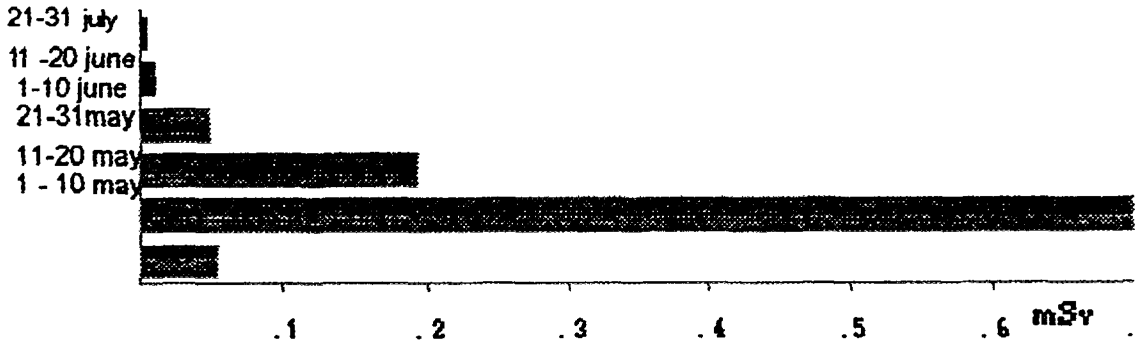


Figure 3 Equivalent dose in thyroid, adult, due to ingestion of milk, mSv .

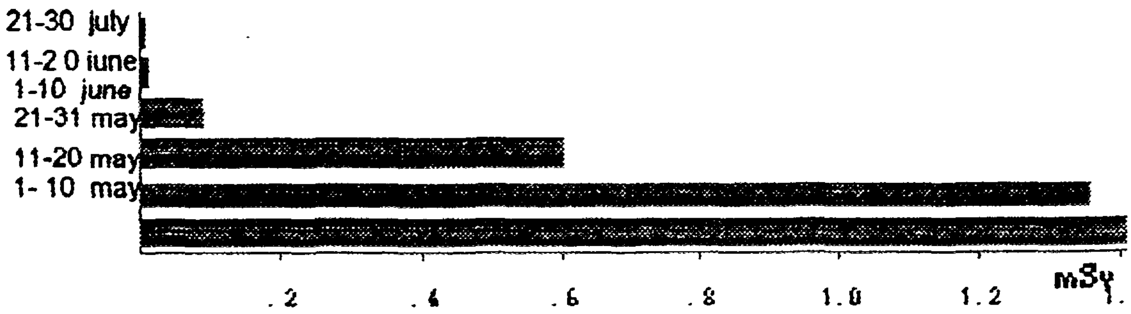
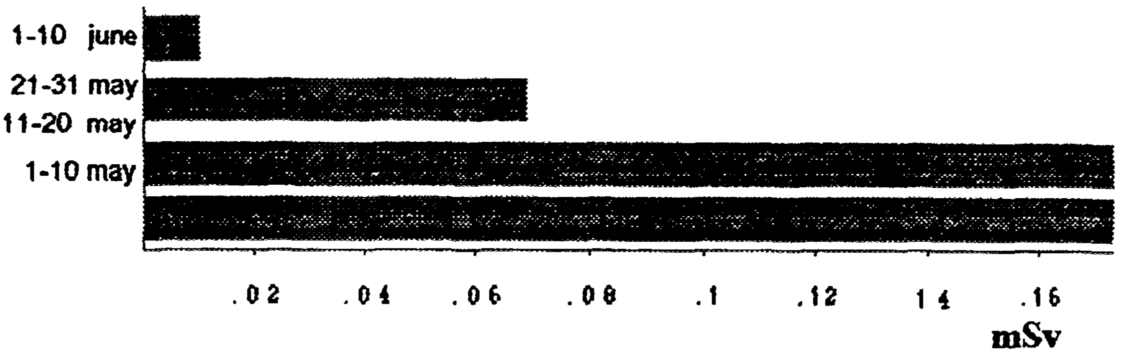
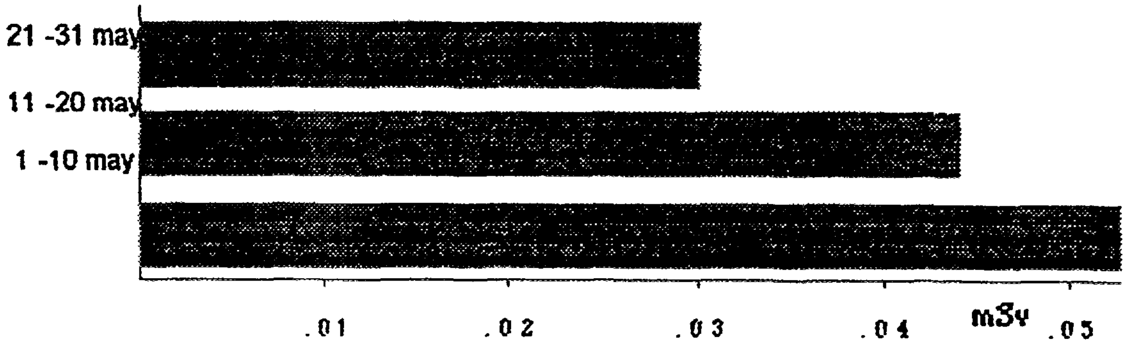


Figure 4 Equivalent dose in thyroid, adult, due to ingestion of vegetables and fresh fruits, mSv .

Vegetables



Fresh fruits



SOCIAL, ECONOMIC AND POLITICAL ASPECTS OF CHERNOBYL IN BULGARIA - ONE CHARACTERISTIC FEATURE OF THE DEVELOPMENT OF THE RADIATION SITUATION

XA9745892

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СОЦИАЛЬНЫЕ, ИКОНОМИЧЕСКЫЕ И ПОЛИТИЧЕСКЫЕ АСПЕКТЫ ЧЕРНОБИЛЬСКОГО ФЕНОМЕНА В БОЛГАРИИ - ОДНА ХАРАКТЕРНАЯ ОСОБЕНОСТЬ В РАЗВИТИЕМ РАДИАЦИОННОЙ ОБСТАНОВКИ

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It is shown a characteristic features of the progress of radiation situation in Bulgaria after the failure in Chernobil, as this was discuss untraditionally. The raised radiation risk for population during one year after the incident is interpreted as function from the unadequate radiation protection policy of the Government at that time. Preconditions for some social, economical and political results after the accident for Bulgarian country are discribed.

Эта публикация представляет развитие радиационной обстановки в Болгарии после аварии в Чернобилье в нетрадиционном аспекте. Повысеный радиационный риск для населения на год после события интерпретируется как функция неадекватной радиационно-защитной политики тогдашной администрации страны. Авторы не политизировают проблему, но десятилетная его давность все еще не преодолена в полно осторожность болгарской обществености к пережитого и ее недоверие к ответствеными институциями.

Ранный период развития радиационной обстановки в Болгарии после аварии определяется с интензитета трансграничного переноса радиоактивного загряз-нителя. Но его тяжесть дефинируется с комплексными обстоятельствами : особености в синоптике региона, совпадение с вегетационным периодом растительности и лактация продуктивными животнами [1].

Это обословило высокую начальную контаминацию основных пищевых продуктах, которая быстро снизилось с 5 до 8 раз в следующих четыри месяца. Компетентные професиональные институции передставили властям долготрайную прогнозу для возможности возникания повторного контаминационного процесса если допустится выкормливание продуктивными животными зимного периода с загрязненным фуражных запасов из ранного послеаварийного периода. Рекомендованы были модели и методы для редуцирования загрязнения животынской продукции, системный контроль пищевых доставок для населения, как и допустимых в экономическом аспекте способы деконтаминации. Недооценивание рисковых эффектов события на здоровье нации, неумелое использование или сознательное неиспользование материально-технических возможностей государства и ее научного потенциала не позволили приложении этих рекомендовании. Предпочитание к конюнктурно-политических и коммерческо-экономических сообра-жении перед радиационно-гигиенными принципами довели к следующим последствиям:

1. Прогнозированный второй контаминационной процесс начался еще в октябр по ноябр 1986 г, а в периоде март-апрель 1987 г содержание цезиевых радионуклидов перевысило установленую аварийную норму с 600 Bq/kg для бараниного мяса с 35 до 45 % от иследоваемых доставок Южней Болгарии. Только 26-37 % с этих партид были ниже нормы для остальных видов мяса (350 Bq/kg). Обще для страны со специфическую активность до 350 Bq/kg были 58 % из обследованных партид, с 350-600 Bq/kg - 20 %, а выше 600 Bq/kg - 22 %, достигающие активность до 7200 Bq/kg. 15-50 % из молочных доставок были неподходящие для консумации при максимальными стоимостями цезиевым радионуклидом до 1200 Bq/kg [1].

2. В логической корелации с этим фактом является динамика инкорпорационного процесса в человеческим контингентом Южней Болгарии, у которых средне-специфическая активность ^{137}Cs + ^{134}Cs за периода майя-июня 1987 г достигла 320 Bq/kg [2]. Эти стоимости являются аналогичными целотелесной активности городского населения Брянской области этого периода (342 Bq/kg). Они в унисоне с констатации United Nations Scientific Committee on the Effects of Atomic Radiation для самую высокую индуцированую эффективную эквивалентную дозу у взрослого населения Болгарии инкорпорированных цезиевых радионуклидов [3]. По коэффициент защиты болгарское население занимает так же одно из крайних мест среди затронутых стран.

3. Экономические последствия созданной ситуации определяются уменшением количества молока для населения в 1987 г, недопускивание определенных партид мяса на внутренной рынке или выключивание с экспортной листе страны и с производственными затруднениями при натурального использования высоко-контаминированных животинских суровин. Все это довело до конкретных финансовых потерии страны [4]. Но они являются несъизмеримыми с бесспорному факту, что одна активная профилактическая позиция властям сбережила бы болгарскому населению примерно 30 % с допольнительному лучевому нагружению вследствие катастрофы в Чернобилье [4].

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ONE DECADE AFTER THE CHERNOBYL ACCIDENT: PAST, PRESENT AND FUTURE. NATIONAL REPORT OF UKRAINE AT THE INTERNATIONAL CONFERENCE ON ONE DECADE AFTER CHERNOBYL

XA9745893

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Десять лет Чернобыльськой катастрофе.
История, настоящее и будущее.

Национальный доклад Украины на международную конференцию в связи с десятилетием аварии на Чернобыльской АЭС.

В докладе изложены основные результаты работ, выполненных за десять лет на Украине с целью изучения последствий аварии на ЧАЭС и уменьшения их воздействия на здоровье людей.

Доклад состоит из трех основных частей. В первой части изложена общая характеристика аварии. Представлены различные восстановленные сценарии аварии в первые дни, данные о составе топлива в реакторе на момент выброса, схема движения радионуклидов при аварии, ядерно-физические и химические характеристики топлива в обьекте "Укрытие", возможные пути обеспечения безопасности обьекта "Укрытие".

Приведены характеристики радиоактивного загрязнения почвы, растительности, воды, воздуха, продуктов питания.

Дается оценка дозовых нагрузок на население, структура дозы внутреннего облучения, вклад естественного фона.

Оцениваются медико-психологические последствия аварии, приводятся данные о динамике заболеваний в загрязненных районах.

Дана оценка воздействия аварии на сельское и лесное хозяйство.

Приведены характеристики наиболее загрязненных районов в зоне отчуждения, эффекты воздействия облучения на окружающую среду.

Во второй части изложены характеристики мер, направленных на уменьшение вредных последствий аварии для здоровья людей. Приведен обзор развития законодательных актов Украины, направленных на защиту потерпевшего населения. Рассмотрены вопросы эвакуации из наиболее загрязненных населенных пунктов.

Дана оценка эффективности контрмер в сельском и лесном хозяйстве.

Приведены результаты работ по обнаружению и дезактивации локальных загрязнений урбанизованных территорий.

Приведен анализ эффективности социальной защиты населения, проживающего на загрязненных территориях, развития системы медицинского обслуживания.

В третьей части приведен анализ последствий аварии на экономику Украины.

Основные результаты научных исследований воздействия последствий аварии на окружающую среду.

Оценка миграции радионуклидов, биологических и медицинских последствий облучения. Оценка эффективности контрмер по уменьшению воздействия аварии на здоровье людей.

PLANNING OF ACTIVITIES IN THE CHERNOBYL EXCLUSION ZONE IN THE UKRAINE

XA9745894

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КОНЦЕПЦИЯ ДЕЯТЕЛЬНОСТИ В ЧЕРНОБЫЛЬСКОЙ ЗОНЕ ОТЧУЖДЕНИЯ НА ТЕРРИТОРИИ УКРАИНЫ

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Разработана концепция деятельности в Чернобыльской зоне отчуждения, расчитанная на период до 2020-2025 г. В ее создании принимал участие большой коллектив ученых и специалистов Украины.

Концепция базируется на существующих нормативно-правовых документах, определяет систему организационных, экологических, медицинских и научно-технических принципов и приоритетов производственной и научно-технической деятельности в зоне отчуждения ЧАЭС. Концепция имеет цель способствовать минимизации экологических и социально-экономических последствий чернобыльской аварии.

В концепции отражены:

- функциональное районирование территории зоны;
- общие положения о деятельности в зоне;
- подходы к превращению объекта "Укрытие" в экологически безопасню систему;
- вопросы обращения с радиоактивными отодами;
- вопросы радиационного мониторинга окружающей среды;
- подходы к организации системы управления зоной отчуждения;
- приоритеты научных исследований в зоне отчуждения;
- первоочередные мероприятия;
- прогноз экологической ситуации в зоне отчуждения и др.

Концепция ... является первым и в настоящий момент единственным в Украине документов в котором наиболее полно и всеобемлюще рассмотрены вышеперечисленные вопросы.

EXPLOITATION OF THE RADIOLOGICAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT FOR POLITICAL AND COMPETITIVE ENDS

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XA9745895

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ИСПОЛЬЗОВАНИЕ РАДИОЛОГИЧЕСКИХ ПОСЛЕДСТВИЙ ЧЕРНОБЫЛЬСКОЙ АВАРИИ В ПОЛИТИЧЕСКИХ ЦЕЛЯХ И КОНКУРЕНТНОЙ БОРЬБЕ.

(Расширенные тезисы доклада)

26 апреля 1996 г. исполнится 10 лет со времени аварии на Чернобыльской АЭС беспрецедентной радиационной аварии, носящей по своим последствиям катастрофический характер. Авария вызвала стойкое радиоактивное загрязнение больших территорий Советского Союза. Общая площадь территории с загрязнением цезием-137 плотностью более 1 Кu/кв. км превысила 130 тыс. кв. км, где проживает около 5 млн. человек. Радиоактивные выпадения были зарегистрированы на территориях большинства европейских стран, а также в США, Китае, Японии, Канаде, Индии и др. Фактически радиационному воздействию, связанному с аварией в Чернобыле, в той или иной степени, подверглось подавляющее большинство человечества. Несомненно, что будущее человечества связано с широким использованием атомной энергии. Поэтому беспрестрастная оценка радиологических последствий Чернобыльской аварии и выводы из нее имеют судьбоносное значение.

К сожалению, такая объективная оценка оказалась затруднительна всвязи с тем, что последствия аварии в Чернобыле были использованы в политической и конкурентной борьбе как внутри Советского Союза, а затем России, Украины и Белоруссии, так и за рубежами этих наиболее пострадавших государств.

Исторически сложилось так, что в первый период своего развития атомная энергетика в СССР и США находилась под патронажем Правительств и всесильных военных научных и промышленных кругов, создавших в то время ядерную мощь своих стран. Однако в США свершилось то, что казалось совершенно невозможным. В семидесятых годах, когда добыча нефти стала сверхрентабельной, развитие атомной энергетики в США было заморожено. В беспощадной конкурентной схватке за сверхприбыль всемогущие нефтяные монополии блестяще использовали возможно единственный шанс. Они сумели найти пути возбуждения у населения страха перед радиационной опасностью, сопровождающей атомные технологии. Эта опасность подавалась как фатальная неизбежность, ибо от населения скрывалась возможность техническими и организационными методами исключить ее полностью или минимизировать. Коварство выбранного нефтяными монополиями пути борьбы с атомной энергетикой заключалось в том, что они повели ее с помощью целого ряда щедро финансируемых международных и национальных экологических организаций, которые по своей сути должны быть сторонниками развития атомной энергетики. На атомную энергетику был умышленно перенесен страх человечества, возникший после применения атомного оружия по городам Японии и ряда американских испытаний в атмосфере на атоллах Тихого океана. Добившись успехов в США силы, борящиеся с развитием атомной энергетики и технологий, перенесли свою активность на зарубежные страны, Однако здесь их успехи оказались менее впечатляющими. В первую очередь это связано с тем, что Франция и Япония, стремящиеся к энергетической независимости, не обладающие сколь-либо значительными ископаемыми ресурсами и получившие горький урок нефтяного кризиса семидесятых годов, твердо взяли курс на развитие атомной энергетики. Закрепилась атомная энергетика в Канаде, Великобритании, Испании, Республике Корея и ряде других стран.

Однако антиядерные силы продолжали и продолжают борьбу. Всплески их активности наблюдались после аварий в Уидскеле и Тримайайленде. Чернобыльская же авария стала их козырной картой.

В СССР антиатомное движение существенного значения до 1986 года не имело. Руководство КПСС и Правительство СССР твердо взяли курс на развитие атомной энергетики. Строгая цензура информации обеспечивала неукоснительное претворение в жизнь этого курса. Поэтому оказать сколь-либо существенное влияние на энергетическую стратегию зарубежные нефтяные монополии не могли. К 1986 г. в СССР находилось в эксплуатации 43 атомных энергоблока суммарной мощностью брутто 30,3 млн. квт. На 20 строительных площадках сооружалось или готовилось к сооружению около 100 атомных энергоблоков. Такое бурное развитие к сожалению сопровождалось снижением уровня организационно-управленческих и технических требований к функционированию советской атомной энергетики. Что в конечном итоге и привело к катастрофе на ЧАЭС 26.4.1986г.

Сейчас очевидна противоречивость условий,сложившихся к этому моменту в СССР и повлийявших на последующие после катастрофы события. С одной стороны созданные в стране условия,государственные структуры и советское общество оказались готовыми к преодолению экстремальной ситуации, сложившейся в результате взрыва атомного блока. Удалось минимизировать последствия катастрофы. Погибло 28 человек, заболело острой лучевой болезнью или получило местное лучевое поражение 204 человек. Хотя на территориях, затронутых чернобыльской радиоактивностью, оказалось несколько миллионов человек, на первом этапе удалось сохранить спокойствие, недопустить необоснованной паники.

С другой стороны, органы власти, компетентные научно-технические специалисты,всилу закрытости советского общества, не сумели обеспечить население,соприкаснувшееся с последствиями катастрофы правдивой, полной и доступной информацией, уберечь его от умышленной и неумышленной дезинформации, чувства беспомощности и обреченности. Это обстоятельство привело к весьма печальным последствиям, возникновению радиофобии, тяжелым психическим заболеваниям десятков тысяч людей.

Первый удар дезинформации об аварии на ЧАЭС был нанесен из-за океана. Он предназначался не только советским людям. Его целью также была атомная энергетика США и других стран Запада. Воспользовавшись отсутствием первоначальной информации из СССР, зарубежные СМИ подхватили выпущенную 29 апреля 1986 г. американскую "утку" "о том, что общее число погибших в аварии на ЧАЭС может составить 2000 человек, 80 человек скончалось сразу и около 2000 по пути в больницу". Для придания большей правдивости и добавления кошмара говорилось "людей хоронят не на обычном кладбище, а в деревне Пирогово, где находится могильник для радиоактивных отходов".

Другой американский эксперт в дополнение к 2000 погибшим сообщает, что уже зарегистрировано 2000 случаев рака. Заявление Москвы сделанное 29 апреля о гибели при аварии 2 человек во внимание не принимались. Наоборот, профессор Гофман из Калифорнийского университета предрекал заболевание раком 1 миллиону человек. Пропагандисты-наемники нефтяного лобби начали хорошо финансированную, продуманную психическую компанию по нагнетанию радиационной истерии, с целью закрытия всех АЭС в США,ФРГ,Швеции,Финляндии,Франции и других стран. В ходе ее подвергались травле ученые, пытавшиеся изложить правдивые оценки последствий аварии, предотвратить негативные влияния дезинформации. Яркий пример тому шельмование профессора Пеллерена во Франции. Не мало грязи выливалось на МАГАТЭ, позиция которого во все времена после аварии остается строго взвешенной.

Вцелом для антиатомных сил постчернобыльская компания оказалась успешной. Прекратили строительство новых атомных энергоблоков США,ФРГ, Швеция,Финляндия и ряд других стран. Парламенты ряда стран приняли на законодательном уровне решение об полном отказе от атомной энергетики. И все же несмотря на колосальное потрясение Чернобыльской аварией мировая атомная энергетика выстояла,оправилась от него и продолжила наступательное развитие.

Для СССР Чернобыльская авария явилась началом цепи процессов и событий, приведших в конце концов к распаду этой могущественной казавшейся монолитом страны. С 1987 г. в СССР начали проводиться не до конца осознанные обществом, но коренные преобразования. Установленная цензура СМИ пришла в противоречие с объявленной политикой гласности, которая в отсутствии законодательной базы была воспринята как вседозволенность и безответственность за публикации. Поэтому все фальшивки о радиологических последствиях аварии, появившиеся в СМИ Запада были опубликованы в советских изданиях и навязаны населению как несомненные истины.

Шельмованию в СМИ подвергались ученые (Ю. Изразль, Л. Ильин идр) пытавшиеся воспрепятствовать возникшей и катящейся по стране волне дезинформации. В это время в СССР начали образовываться многочисленные экологические движения и орнанизации. Е. Велихов, Р. Сагдеев и А. Яблоков стали основоположниками национальной организации "Гринпис", деятельность которой сразу приняла резкую антиатомную направленность. Путем дезинформации населения "Гринпис" приступил к реализации далеко идущего замысла по разрушению советского промышленного и оборонного потенциала и в первую очередь атомного комплекса. Обладая широкими финансовыми возможностями "Гринпис" фактически координирует и направляет работу большинства ныне действующих в России международных и национальных организаций экологического толка. Используя дезинформацию населения этим организациям удалось добиться резкого падения радиологических знаний, снижения и без того невысокой экологической культуры, что позволяет им манипулировать общественным мнением.

Особенностью постчернобыльского периода истории СССР было появление в советском обществе небольшой но активной прослойки советской буржуазии, так называемых "демократов", которая прикрываясь демократической фразеологией начала открытую подготовку к ликвидации социализма и захвату власти. В борьбе за депутатские мандаты всех уровней и политическую популярность ими успешно была разыграна "чернобыльская карта". "Демократы" умело разжигали и направляли гнев народа за катастрофу на ЧАЭС на КПСС и социализм. На разжигании радиологической истерии сумели добиться высоких мандатов в Советах, войти в руководство правительственными организациями экстремистски настроенные руководители организаций экологического толка С. Шушкевич, Н. Воронцов, А. Яблоков, Б. Немцов, М. Лемешев и другие.

Использовали Чернобыльскую аварию с целью развала СССР и захвата власти в своих республиках и националисты С. Шушкевич, Л. Кравчук, Ю. Щербак, А. Ярошинская, руководители "Саюдис" в Литве, армянские националисты и многие другие убеждали население, что атомная энергетика навязана их народам Москвой, дабы нанести ущерб нации. В доказательство этого отыскиваются и цинично демонстрируются н весь мир фотографии детей-уродцев, уродливых телят, жеребят, по сят. заболевания которых не имели никакого отношения к радиационн и воздействиям, а порою и рожденных далеко от чернобыльской зоны.

В создание р диологического психоза в обществе внесли свой не малый вклад воз икавшие как грибы после дождя различные общественные органиэ ции, объединявшие людей, в той или иной мере участвовавших в ли: видации последствий Чернобыльской аварии. Их существование напр мую оказалось связанным с денежными фондами и средствами, которы они умудрялись получать от правительств страны или региона государственных, коммерческих и общественных организаций, отдел ных лиц. Они оказались и остаются заинтересованы в нагнетании обществе радиационного психоза. Безбедное существование этих о ганизаций зависит от величины взносов или пожертвований, котор е в свою очередь определяются демонстрацией заболеваний и стра аний их членов, которые во всех случаях напрямую связываются с радиологическими последствиями аварии. Ярким примером вышибания денег за счет нанесения ущерба психическому состоянию миллионо людей, явился 24-х часовой телемарофон, проведенный российским В и организацией Чернобыль-помощь. Этот антигуманный шабаш за ончился психическими растройствами у десятков тысяч россиян и ми лионными суммами на счетах в иностранных банках его устроителей.

К сожалению н до констатировать, что в поддержании определенного психическо о напряжения у населения, задетого чернобыльской бедой заи тересованы и некоторые государственные органы, нужность которых и определяется этим напряжением. Иногда их усилия в этом далеко благодарном деле принимало курьезный характер. Так было, н пример, с оценкой результатов "Чернобыльского проекта". Пытаясь провергнуть неустраивающие их выводы, сделанные большой групп й ученых различных стран, некоторые недальновидные представите и правительств Украины и Белоруссии, без каких-либо доказател ств, опустились до оскорблений и обвинений в недобросовестности. После чего они же пытались получить существенную помощь от ООН, в которой им было отказано.

Значительную долю вины в нагнетании после аварии на ЧАЭС радиационного психоза несут средства массовой информации. Зачастую журналисты забывают, что преувеличение радиационной опасности для человека также аморально как и ее занижение. Через 10 лет после аварии СМИ обязаны принять все меры, чтобы снять необоснованное радиологическое напряжение в обществе.

В целом проблема объективной оценки радиологических последствий Чернобыльской аварии оказалась глубоко политизированной, что существенно усложняет ее решение.

EVOLUTION OF REGULATION RELATED TO THE CHERNOBYL ACCIDENT

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1. INTRODUCTION

'Classical' principles of radiological protection are based on radiation doses, intervention levels and effective countermeasures. Clear and logical in principle, these basic parts need a specific clarification on each after-accident period. Being unavoidable and useful on the first early stage, 'the classical' principles and criteria meet specific obstacles in introduction and practical application on the next, long-term stage.

The 'classical' pattern of radiological protection considers mostly the radiation factor. The choice of protective measures is governed by effective doses, both received and projected, also established and adopted intervention levels, respectively. The effectiveness of the countermeasures is measured by the value of an averted dose.

The lessons learned from Chernobyl show that the above single-factor pattern of radiological protection is appropriate only at an acute post-accident phase. In that period (days and weeks after an accident) the radiation factor prevails and basic countermeasures are proceeded from pre-arranged intervention levels.

At the next long-term phase (months, years after the accident) there is enough time for a human factor to come fully into force. This factor implies the psychological and social acceptance, by the public, of the countermeasures to be implemented. It implies the response of the public to their implementation, the reflection of the situation by mass media, the reaction of Legislative and Administrative Bodies too.

2. EVOLUTION OF REGULATION RELATED TO THE CHERNOBYL ACCIDENT IN THE FORMER USSR

Former USSR had a great experience in off-site remedial actions in the case of severe radiation accidents at the Southern Urals. Unfortunately, that experience was not reflected in the Guides regulated protection of the public. Only intervention levels for early off-site countermeasures were implemented in the Emergency Plans and Guides [1]. They were realized on the early post-accident period [2].

The management of post-accident countermeasures in the former USSR was implemented under conditions when neither domestic guides nor recommendations of international organizations were not complete or perfect. The main problems arose especially in respect to measures at the intermediate and long-term phases. The Radiation Safety Standards of the former USSR - NRB-76/87 contained only one item, concerned with protection of the public in the case of radiation accident. According to it in the case of each accident the USSR Ministry of Public Health should to establish the special requirements on the public exposure. The USSR Ministry of Public Health had the USSR National Commission on Radiation Protection as a consultative body in the field of radiation safety.

2.1. '35 rem' Concept

In 1988 the USSR National Commission on Radiation Protection developed the 'Concept of safe residence in populated areas contaminated after the Chernobyl accident'. That Concept was adopted by the USSR Ministry of Public Health on 22 November 1988 and is well known as '35 rem' Concept.

The Concept was based on using a lifetime dose as a measure of the lifetime radiological hazard. It should be noted that the Concept was a simplified reflection of the scientific and practical experience of that time and the situation established in 1988-1989 in the regions affected by the Chernobyl accident. In fact the Concept only corrected the intervention levels for relocation adopted in existed Emergency Plans [1]. The main principles and criteria of '35 rem' Concept are the following [3]:

1. To establish limit of the individual lifetime dose 35 rem applied to the summary doses resulting from external and internal exposures.
2. The observation of represented dose limit is regulated by the mean individual dose equivalent in the critical group of each populated area.
3. The fixed standard includes the doses, which the population had been exposed to since April 26, 1986.
4. The fixed standard does not include doses incurred from natural background radiation.

The lifetime dose intervention level was established to limit late health effects caused by radiation exposure. On the territories where the predicted lifetime dose would not exceed that value, the limitation withdrawal was suggested from 1990. In areas where it was envisaged lifetime dose intervention level of 35 rem would be exceeded, relocation should be made. In areas where it was envisaged that lifetime dose level would not be exceeded, no actions are required. The one level system of making decisions on protective measures would not allow any optimal use of the whole complex of possible protective measures.

2.2. Chernobyl 1991 Concept

In 1988 - 1990 the '35 rem' Concept was realized in some Governmental decisions on liquidation the consequences of the Chernobyl accident. But on 25 April 1990 because of hot discussion it was rejected by the Supreme Soviet of the USSR. The Soviet Government entrusted the Academy of Sciences with the examination of that Concept and all its possible alternatives. The goal of that work was to elaborate a synthetic position, which could be acceptable for the concerned Republics.

The Chernobyl 1991 Concept of protective post-accident measures was drafted by the end of 1990 and was approved on 8 April 1991 by the USSR Government [4]. Authorized Bodies of Belarus, Russia and the Ukraine worked out and adopted also their versions of the Concept, which were in main principle points very similar to the All-Union Chernobyl 1991 Concept.

The main goal of that Concept was the implementation of the clear dose principles in decision making on the late phase of the post-accident remedial activity. Main points of the Chernobyl 1991 Concept are the following.

1. The effective dose due to the Chernobyl accident shall be the basic index for making decisions on protective measures, their character and scale, as well as compensating for damages.

2. The excess (over the natural and technogenic radiation background for given locality) of the public exposure from the Chernobyl fallout is permissible. It doesn't demand any intervention if an average annual effective dose is lower than 1 mSv for 1991 and following years. At the level of 1 mSv and lower, the conditions of living and working activity of the population does not require any restrictions.

3. At a higher level than 1 mSv per year (over the natural and technogenic background), protective actions should be taken. Achievement of these goals should be optimized with the condition that an average individual effective dose equivalent does not exceed 5 mSv in 1991, with a maximum decrease of this limiting level up to 1 mSv in future.

4. Voluntary relocation can be reckoned among the countermeasures. Each person living in a contaminated territory shall have the right to make own decision about continuing to live in the given territory or going to another place of residence. That decision must be based on unbiased information about the radiation situation, socio-economic and other aspects of life. Any decision adopted should not give a direct economic advantage.

2.3. Resume

The Chernobyl 1991 Concept together with '35 rem' Concept could be the background for more appropriate regulatory documents to meet requirements for protecting the public in the case of radiation accident. Unfortunately, no steps were made on that way. In 1991 basing on the Chernobyl 1991 Concept the Chernobyl All-Union [5] and Republican Laws were worked out and adopted by the Supreme Soviets of the USSR, the Ukraine, Belarus and Russia. These laws turned out to be considerably different by some their principle points from the relevant Concepts and each other.

Since mid-1991 the practical activity on the elimination of consequences of the Chernobyl accident has been regulated by the Law [5]. However it became clear already in 1992 that the regulatory documents connected with both the elimination of consequences of the Chernobyl accident and other applications needed to be further improved and developed. It was caused by several reasons. Main of them are the following.

1. In the Law there are serious contradictions and unjustified principles that prevents from optimal implementation of long-term protection and restoration measures. In the first part of the Law [5] ('General Provisions') the public dose is taken (agree with the Concept [4]) as a main index for decision making.

It established that average annual dose equal to 1 mSv is acceptable and does not require any intervention (non-action level). Nevertheless inspire of these justified provisions another parts of the Law are based on another index: a level of soil contamination by ^{137}Cs. This index was used for zoning the contaminated territories since 1986. According to the Law it must be used for decision making in the territorial zoning, population relocation and other countermeasures allowances and compensations. Between this index and the annual or residual doses there are no direct relationships.

2. The implementation of the Law created additional social problems. By the Law all territories with contamination as low as 1 Ci/km^2 were determined as 'suffered from the Chernobyl accident'. About 2,600,000 peoples lived on that territories in 1992. Annual doses for about 93% population of 'suffered territories' did not exceed 1 mSv in 1992 [6].

3. POST-ACCIDENT MANAGEMENT IN RUSSIA SINCE 1992

The Chernobyl 1991 Concept [4] and the Law [5] have limited application. They were relevant only to the situation, turned out in 1991 and following years in the regions affected by the Chernobyl accident. In Russia there are several contaminated regions besides the regions suffered from the Chernobyl accident. Since 1992 the issues of radiation protection, social rehabilitation and economic compensation in these territories have been under consideration by scientists and local and state authorities. The experience from these areas was used to reconsider the past recommendations on intervention strategy.

Considering these demands on improved regulation documents it was planned to develop in 1992 - 1995 new improved recommendations and guides on carrying out protection and restoration measures after nuclear accidents. The Russian NCRP, organized in 1992 by the Decree of the Government of the Russian Federation, and the Chernobyl State Committee began this work considering accidents occurred in the past and probable future one's. It was understood that in these documents one should

- consider as interacted all post-accident phases: early, long-term and a final restoration (rehabilitation) one's,
- develop in more details not only radiation but also social protection aspects.

A lot of items of the Chernobyl 1991 Concept became the 'points of growth' for new regulatory documents. Now two Concepts now are finished in development. That Concepts develop aspects of the Chernobyl 1991 Concept related to social (in more details - medical) rehabilitation of the suffered public. Briefly they were presented in the proceedings of the Minsk conference [2].

The first step on the generation new set of regulatory documents was the Altai 1993 Concept [7]. It was developed following the Russian Government commission (1992) decision to work out a program of rehabilitation of the public in settlements of Altai region, located in the zone affected by nuclear weapon tests on the Semipalatinsk Test Site. In terms of residual effective doses that Concept determined two categories of exposed persons and established the collective or individual social protection measures for them.

That Concept was developed and substituted by 'Concept of radiation, medical, social protection and rehabilitation of the public of the Russian Federation affected by accidental exposure' [8]. The main goal of that Concept was to make proposals on changing radiation, medical, social protection and rehabilitation strategy in the Russian regions suffered from the radiation accidents and nuclear weapons test many years ago. Medical and social protection and rehabilitation of the public in the Concept is based on the definition the cohort of exposed persons, cohort of persons, suffered from the accident and high risk cohort. That definitions are made in terms of life-span residual effective or equivalent doses. The collective and individual protection measures are specially envisaged for each cohort. The National Radiation and Epidemiologic Register was appointed as the organization base for all medical and social actions.

More general and principle regulation documents are now in the stage of preparation and adoption. One of the most important among them is the new Radiation Safety Standards for Protection Against Ionizing Radiation - 'NRB-96', prepared by joint working group of Belarussian and Russian scientists. That working group worked in a strong contact with NCRP of Russia and Belarus. That document includes chapter appeared as a result of analysis of our Chernobyl experience: 'Requirements to restriction the public exposure in emergency situations'. It includes the guidelines for intervention levels in emergency exposure situations on the acute and intermediate post-accident period. The special annex to that chapter has a requirements for zoning of the contaminated territories on the early, intermediate and restoration post-accident period.

In 1996 the adoption of the new Altai 1996 Concept is expected [9]. Its aim is to optimize the social and medical remedial measures for Altai inhabitants, suffered from the Nuclear weapon tests. The opportunity of optimization of the rehabilitation measures is based on development of the methodical approaches, computer database and codes by valuation of dose of a exposure, risk and health condition of the population. All this permits to evaluate consequences of the exposure with accuracy acceptable for medical practice. This may give particular, justified and address recommendations for realization of practical measures with use the regulatory documents on protective and restoration measures after the accidents.

The medical protection of the population against consequences of emergency exposure consists of a advance establishment of the persons, being direct carriers of the risk of realization of consequences of a exposure. The Concept has a requirements

- to formation from them the groups of increased risk;
- to prevention of potential stochastic effects;
- to application of radical measures at early stages of their manifestation.

The following three documents are now in work in the frame of the Russian federal research program (the Chernobyl case study):

- Recommendations on intervention levels and strategy of remedial actions after a nuclear accident;
- Recommendations on optimization of intervention and remediation actions after a nuclear accident;

- Recommendations on risk analysis in application to protection and remediation actions after a nuclear accident.

All these documents are coordinated one with others. The first versions (drafts) of them were adopted by Russian NCRP in December, 1994. The aim of that activity of Russian NCRP is the adoption of national experience of liquidation the consequences of large nuclear accidents and nuclear tests into the national practice of remedial actions and national radiation safety standards.

The main features of this new set of regulation documents are:

- combined consideration of all phases of post-accident activity,
- going outside pure radiation protection and taking into radiation as well as non-radiation risks,
- three sets of decision making dose levels,
- developed definition of a critical group, in which a possibility to receive not only the highest doses but also the highest risk is taken into account.

The system of Intervention levels includes THREE sets:

1. General Intervention Levels (in projected doses), which establish the strategy of intervention;
2. Specified Intervention Levels (in avertable doses and risks) of radiation protection;
3. Specified Intervention Levels (in residual doses and risks) of social protection.

The general intervention levels content two principal levels:

- upper dose level (the dose constraint) which demands to introduce any countermeasures not to allow to receive by people doses above this level;
- lower dose level which plays the role of a non-action level.

The development of these regulation documents will continue in 1996.

4. CONCLUSIONS

Now there is a real hope to have in coming future considerably developed and improved regulation documents of a new generation. One of the main task during their preparation is to learn all necessary lessons from the Chernobyl and other accidents, post-accident activity and results of relevant scientific research.

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XA9745897

SOCIAL AND PSYCHOLOGICAL CONSEQUENCES OF THE CHERNOBYL ACCIDENT IN YUGOSLAVIA

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1. INTRODUCTION

A day before the accident in Chernobyl, Yugoslavia was the country with nuclear energy programme, one nuclear power plant and strong affiliation towards nuclear fuel cycle. Public relation programs did not existed. The majority of information were classified and public trust was almost undisturbed. It was almost possible to say that the public attitude was indifferent.

A month later everything was quite different. The public has been awaken from sleepy unconscious. The public reaction moved from surprise, interest and hunger for information to chronic suspicion. In years later phobic and radiophonic reaction become common place.

The final consequence today is huge magnifying lens of public eye, watching carefully everything connected with radiation, even trivial matters, and thus forming strong pressure to decision makers.

2. MEDIA REACTION IN YUGOSLAVIA AFTER THE ACCIDENT IN CHERNOBYL

Public relations and public information is analyzed through content analysis of articles from daily newspaper "POLITICS" (POLITIKA) in may 1986 and summer 1991.

Chernobyl accident was major headline in first 10 days, with series of articles on 2nd, 3rd and 7th pages. Daily reporters transferred information from various world sources: objectively and with restrain concerning their personal attitudes. However, the average reader was faced with series of articles, often vary contradictory one to another: "Increased radiation in Europe", and from Kiev "Just lack of news, but 100 000 persons participated parade on 1st of May." Few days later: "45 000 people have been evacuated from Kiev", but in Zlobyn: "All preventing measures are removed, work can continue." One day you can read that rain would have positive effect, but very next one there is an article with the title:" Rain would increase problems".

Titles had recognizable note of negative emotionality or they were written as disturbing question on which you will not find an answer in the text that follows: " Anxiety is decreasing, concern remains", "Destructing mind of science", "Threats from clouds - how long?", "How to berry reactors ?" .

What was the cause of accident, what is the real dimension of health endanger, what are countermeasures on personal and collective level, were the basic unanswered questions during the first month after the accident. It was not possible to find an explicit answer at that time.

The article with title: "Human error caused the accident" appeared on May 3rd, May 7th the title was "How the accident have happened", May 10th the title was "The real causes still unknown" , and on May 13th "What is the real information?"

Very soon after that, political and economical point of view become the most important and the only one present in daily news: "25 million $ lost due to import ban from EU". The Chernobyl accident was entitled as :" The worst scenario" or " The accident of accidents".

Journalists have represented expert opinions instead of experts themselves. That have caused that published attitudes were accidentally or wilfully distorted and incorrect.

Responsibly ministries and experts felt the necessity to give relevant information to "calm down" citizens, but even their information were contradictory among each other. It was obvious that there was not organized public relation service in this field, especially in the emergency situation.

3. DISCUSSION

The formulation of presented attitude is equally important as its content. To achieve better understanding of radiation risks, experts have used different comparisons to clearly express their thoughts. But sometimes that have been done with side effects. However, those comparison were unconvincing for common person, achieving contrary effects. One of those comparison appeared several days after the accident, trying to calm the public:" It is more danger to watch colour TV then eat strawberries". Of course, up to that time the majority of the public have no idea about any risk of watching colour TVs.

The most of the statements of experts and politicians were published without signatures.

From time to time, different articles ranged from pathetic tone to cenacle ones, have appeared with different metaphors such as: "Chernobyl - Pandora's box" or "To whom ring the bells of Chernobyl" and so on.

Chernobyl accident and all that have happened around it and in connection to it were during the year 1986, and even later, desirable subjects for manipulation in our areas. The main cause for this situation is the "absence of the institution of public relation and the lack of professional and social responsibility for public appearance in the field of radiation protection" (1).

As a result, in short time intervals our country become the field of different scandals in the field of ionizing radiations. It is not surprisingly that "common people" reacts on those happenings unexplainable nor logically nor by common sense. After the accident in Chernobyl, it was very easy to convince someone that it is possible to burn radioactive waste in ordinary factory halls. And that have happened only 5 years later.

Insufficient public information was the problem after the Chernobyl accident and it have remained satisfactorily remained up to date.

As a result of strong public pressure and distrust, several new explicit statements are introduced in related regulations.

Firstly, from the country with nuclear energy program, Yugoslavia become the country with explicit nuclear power plant planning and building ban. It is also forbidden to import radioactive waste of foreign origin and to dispose it on Yugoslav territory.

It is explicitly stated that everything concerning human health, including subjects of ionizing radiations can not be confidential. It is still hard to develop strong public trust. It is still possible to make a good story from ordinary granite stones producing cancers.

4. CONCLUSION

One of the positive elements of this problem, 10 years later is slightly changed clime in media. There is still a lot of journalist trying to make politically sensational article in this filed, trying to discover (or even invent) something big and hidden. But there is also a change in some of the papers, assigning ceratin journalist to deal constantly with the subject of ionizing radiations. There are TV panel discussion on some burning subjects, and experts become steadily present in medias, in informative, educational and scientific programs.

In Yugoslav new Radiation Protection act, still in preparation there is declared state obligation to solve the problem of central storage centre for radioactive waste disposal in next 6 years. In accomplish this task, it is necessary to start solid, scientifically grounded public information program. Public was for a long time only frightening it is time to change the approach.

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SESSION 7

INFLUENCE OF THE AFTERMATH OF THE CHERNOBYL ACCIDENT ON THE DESIGN OF A METHODOLOGY FOR THE DEVELOPMENT OF AN INTEGRATED ACCIDENT MONITORING SYSTEM

XA9745898

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Влияние последствий Чернобыльской аварии на формирование методологии развития интегрированной система мониторинга аварийных ситуаций

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Уроки Чернобыльской аварии привели к необходимости пересмотреть некоторые аспекты концепции мониторинга аварийных ситуаций. Анализ последствий показал, что наличие к моменту аварии развитой, в современном понятии этого слова, системы радиационного мониторинга позволило бы значительно смягчить воздействие аварии на население и природную среду, особенно в ее ранней стадии.

Развитие современной методологии мониторинга аварийных ситуаций, в том числе обусловленных радиационным фактором, должно исходить из понимания тесной взаимосвязи между опасными природными явлениями и техногенными авариями, последствия которых могут привести к экологическим катастрофам. Все виды катастроф создают единую замкнутую систему, в которой повышение вероятности развития одного вида опасностей ускоряет проявление других видов. Примером могут служить опасные явления (смерчи, пожары и др.) на территориях, загрязненных в результате Чернобыльской и других радиационных аварий, итогом действия которых становится дальнейшего распространение радиоактивного загрязнения окружающей среды со всеми вытекающими отсюда последствиями.

Постоянное увеличение числа синергетических или многоступенчатых катастроф, когда опасные природные явления вызывают технические катастрофы, которые, в свою очередь, часто приводят к резкому ухудшению экологической обстановки заставляет специалистов стремиться к идее создания единой системы мониторинга опасных явлений.

Развитие таких катастроф значительно усложняет принятие мер по их ликвидации, поскольку профилактические меры, направленные на предупреждение опасных природных явлений, оказываются неадекватными в случае совместного развития бедствий природного и техногенного характера. Аварии в современной техносфере по своим масштабам и тяжести последствий сравнимы уже с природными катастрофами, а потому перестают быть "национальным достоянием" отдельно взятых государств и требуют совместных действий всего мирового сообщества по обеспечению защиты населения и природной среды.

Корректный выбор и своевременное применение адекватных контрмер могут значительно снизить ущерб в условиях аварийной ситуации. Для выбора эффективных контрмер лица принимающие решения (ЛПР) должны учитывать разнообразные характеристики, определяющее специфику и условия развития аварийной ситуации. Характеристики аварийной ситуации могут изменятся как результат применения контрмер, что делает задачу ЛПР еще более трудной. В такой ситуации практически невозможно принять разумное решение без постоянно действующей системы мониторинга и специальных средств информационной поддержки, а учитывая международный характер проблемы - объединенной системы мониторинга и единой компьютерной технологии информационной поддержки принятия решений.

Таким образом реализация интегрированной системы мониторинга опасных явлений возможна только при условии создания единой международной информационной инфраструктуры, включающей систему наблюдения, сбора и обработки данных. В рамках такой инфраструктуры становится возможной разработка теории и практических методов обеспечения безопасности в рамках распределенной системы поддержки принятия решений.

Вопросам реализация этих важных и своевременных идей в практике работы Федеральной службы России по гидрометеорологии и мониторигу загрязнения окружающей среды (Росгидромет) посвящен данный доклад.

В структуре Росгидромета, создается интегрированная система оперативной оценки и прогноза состояния загрязнения природной среды при аварийных ситуациях техногенного характера. Детальное знание гидрометеорологических условий при тех или иных авариях - необходимый компонент этой системы. Поступающую для этих целей в Оперативный (кризисный) центр Росгидромета гидрометеорологическую информацию, циркулирующую по каналам связи, кроме того планируется использовать для создания постоянной системы мониторинга опасных природных явлений. Разрабатываемую же совместно с концерном Росэнергоатом Министерства РФ по атомной энергии и рядом западноевропейских организаций (в рамках проекта RODOS Европейской комиссии) интегрированную систему поддержки принятия решений при ядерных авариях предполагается дополнить подобной системой при природных опасных явлениях и создать основу для развития в перспективе единой системы мониторинга и раннего предупреждения аварийных ситуаций техногенного и природного происхождения.

XA9745899

CHERNOBYL ACCIDENT CONSEQUENCES IN GERMANY: NUCLEAR SAFETY AND RADIATION PROTECTION

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1. Working Programme of the Government of the Federal Republic of Germany on the Consequences of the Chernobyl Accident

A working Programme of the Federal Government was initiated on 26 May 1986 to cover all aspects of nuclear safety and public health, including research and public affairs in the light of the European and international activities resulting from the accident.

This programme included:
- legislation to introduce a programme for radiation protection and large-scale environmental surveillance
- improvements on emergency preparedness regulations
- review of the current safety status of all German nuclear power plants; intensifying research on severe accidents
- international co-operation on information and help in the case of nuclear accidents

2. Programme for Radiation Protection, Environmental Surveillance, and International Co-operation

In December 1986 a new Radiation Precautionary Law (Strahlenschutzvorsorgegesetz) entered into force in Germany. It has two main objectives:

- the optimisation of radiation protection in situations with a large-scale contamination of the environment
- the permanent surveillance of the environment.

The specific regulations of the law cover the following areas:
- the establishment of a nation-wide radioactivity information system IMIS
- the assignment of the competence for the assessment of the results of the radiation surveillance to the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU)
- the authorisation of the BMU to establish and enforce national dose- and contamination intervention levels
- the authorisation of the competent Federal Ministries for Health, Agriculture and Environment to impose restrictions on contaminated food and feed
- the authorisation for border entry control in emergency situation.

In 1987 the German Commission on Radiation Protection (SSK) established national dose intervention levels and a methodology for the determination of secondary contamination levels. Upper limits of the contamination of four types of food and of feed and four classes of radionuclides have been established by decisions of the Councils of the European Community in 1989 and 1990. The upper limit of the I-131 contamination of milk for example is set to 500 Bq/kg.

International agreements on early notification and mutual assistance of the IAEA and the European Community have been established in 1986 and 1987, respectively. On the basis of bilateral agreements with France, Russian Federation, Poland, Czech and Slovak Republic technical systems for the exchange of radiological data and information have been established.

The establishment of the nation-wide radioactivity information system IMIS was completed in 1993. IMIS consists of five nation-wide networks for the permanent surveillance of the
- γ-dose rate near ground (2150 stations),
- activity concentration in the air (50 stations),
- γ-dose rate in rivers as well in the coastal regions of the North Sea and the Baltic Sea.

The networks operate in an automatic mode. They provide early warning messages to the competent authorities. In emergency situations data collection is every two hours. IMIS also includes the operation of computer-based codes for the diagnosis and prognosis of the long-range atmospheric transport of radioactivity and for the assessment of the dose and the radiological situation of the environment. A total of 43 authorised laboratories in the 16 federal states of Germany is in permanent operation. The main emphasis is the surveillance of the food chain.

Computer-based information systems provide the technical services which are required for a standardised collection, processing, and visualisation of the data as well as for the fast exchange of information between the 60 institutions which participate in IMIS and with international organisations.

3. Safety Review Programme by RSK and its Results

Programme

Shortly after the accident of Chernobyl the Federal Government of Germany launched a programme to review the safety of all operating nuclear power plants in Germany in the view of this accident. The competent Federal Minister in charge of nuclear safety asked his advisory body, the Reactor Safety Commission (RSK), to perform this review.

RSK Report

The Reactor Safety Commission presented its results in its "Final Report on the Results of the Safety Review of the Nuclear Power Plants in Germany" on 23 November 1988. This report covered in its main parts generic statements relevant to all nuclear power plants as well as plant specific conclusions for individual plants. In addition, periodic safety reviews on ten year intervals were proposed for the future.

Summary of conclusions and results

In general the RSK stated, that the safety of the German NPPs is based on a well balanced defence in depth concept and that the corresponding equipment is adequate to cover all necessary precautions. The safe operation of the plants is assured.

To further reduce the already very low risk of nuclear accidents, the RSK recommended to consider severe accident management measures with the aim of core melt prevention or mitigation. These proposals include:

- administrative and operational measures taking advantage from the capability of the operational systems
- assuring the direct current power supply for safety related systems using batteries for a minimum time of 2 -3 hours,
- secondary bleed and feed for PWR
- measures concerning hydrogen distribution and combustion
- sampling system for the containment atmosphere
- venting system for the containment to prevent its failure including filters for aerosols and iodine
- filtering of the air supply for the main control room
- diverse pressure control for the reactor pressure vessel of BWR

All German utilities agreed to voluntarily implement accident management measures and to carry out Periodic Safety Reviews (PSR). These PSRs include a probabilistic safety assessment and are supplementary to the routine and legal regulatory control.

4. Support to Enhance the Safety of Nuclear Power Plants of Soviet Design

Because of its high standard in nuclear safety technology, Germany has taken a leading function in the support of the New Independent States (NIS) and Eastern European Countries in improving nuclear safety. In addition to its involvement in the G7 Action Programme from 1992 and in the EU-Programmes TACIS and PHARE a number of bilateral programmes have been started, covering the following aspects.

Support for licensing authorities, regulatory bodies and reactor personnel
This programme covers training, technical equipment and qualification. More than 20 seminars with over 600 participants have been carried out. Over 200 individuals from reactor shift personnel have been trained in the simulator centre of Greifswald.

Supply of testing equipment
For the VVER-1000 and VVER-440 nuclear power stations in Balakovo and Rovno testing and inspection equipment was made available, e.g. manipulator for reactor pressure vessel testing, ultrasonic testing probes. It can be expected, that this pilot project will have a positive effect also on other NPP's.

Safety analyses and calculation codes for accident analyses.
Already since 1989 a scientific-technical co-operation on nuclear safety research is in place. Within joint projects western procedures and methods of safety analyses (e.g. calculation codes) are fitted to soviet types nuclear reactors and tested. This qualifies the Eastern European experts to successfully use these codes for further safety analyses to enhance the nuclear safety of reactors.

This support Programme, in place since 1991, will continue. By the end of 1995, the total expenditures exceeded 130 million DM.

XA9745900

NUCLEAR EMERGENCY PREPAREDNESS IN THE NETHERLANDS

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1. ORGANISATION

The Dutch organisation for nuclear emergency management (Fig. 1) has been described in previous papers [1, 2, 3]. Briefly, the Ministry of Housing, Spatial Planning and Environment (VROM) and the Ministry of the Interior (BIZA) coordinate the input of all other Ministries and agencies at the government level, and provide the general strategy for dealing with the situation at hand. Any indication of a possible nuclear incident may alert the organisation. Signals indicating such incidents are continuously collected by the Emergency Management Department at VROM in The Hague.

An expert group is permanently available for the evaluation of serious warnings, either via bilateral or other international contacts (IAEA, EC, neighbouring countries) or through the Dutch early warning monitoring network via the National Institute of Public Health and the Environment (RIVM). The chairman of this evaluation group has the authority to decide on whether to start up the National Organisation for Nuclear Emergency Management. Its start means the installation of a Policy Team of Cabinet Ministers or their representatives, and the involvement of many authorities and organisations at the national, provincial and local levels.

For many tasks standard procedures, tested on a regular basis, are available to ensure a coordinated effort in collecting information. A combination of prognostic modelling techniques and a default monitoring strategy forms the basis for situation-specific action. Almost all research institutions in the Netherlands related to radiation protection participate in the technical information organisation. The Technical Information Group (TIG) coordinates the modelling efforts and the monitoring programme, and collects all relevant data, either directly, from institutions that are represented as Support Centres in the TIG, or indirectly, via RIVM. Support Centres are, for instance, the Royal Netherlands Meteorological Institute (KNMI), the National Institute for Inland Water Management and Waste Water Treatment (RIZA), the Institute for Quality Control of Agricultural Products (RIKILT) and the Health Inspectorate of Food and Commodities (IGB/KvW).

The TIG occupies a central position in the flow of technical information and in the preparation of situational reports and advisory activities for decisions at the policy level. It is supported in this task by RIVM. An Information and Documentation Centre at RIVM provides model calculations on the dispersal of emitted radionuclides, effective doses and the prognosis of the accident, and integrates all monitoring data. Thus the tools are available to validate and possibly improve the model calculations by

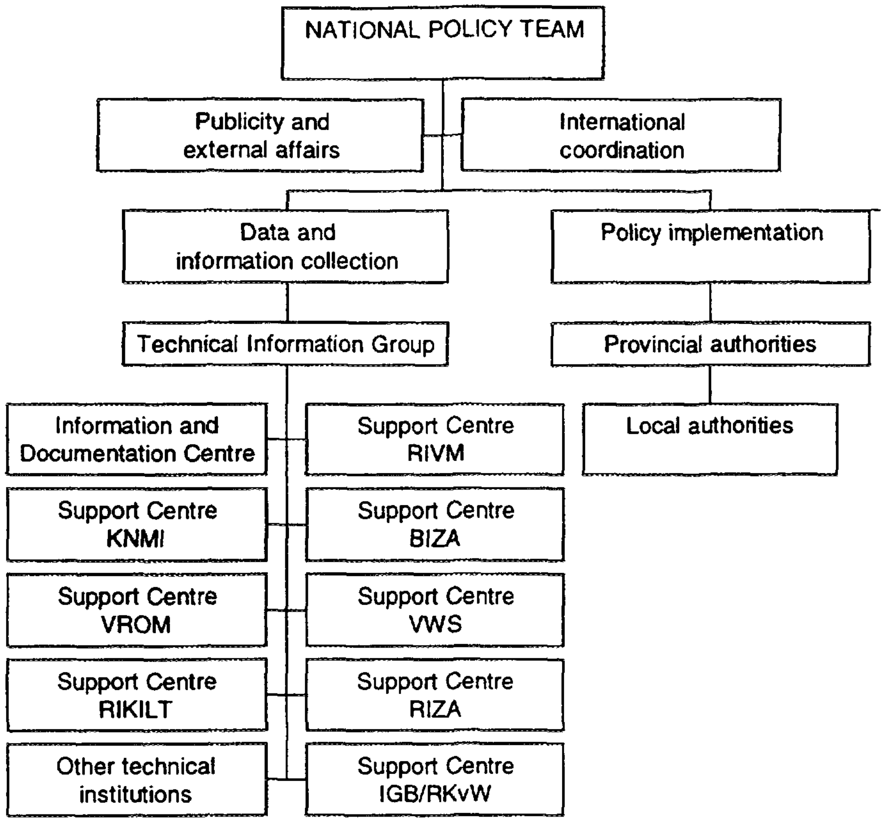

Fig. 1 General outline of the Dutch organisation for nuclear emergency management.

the results of actual measurements. RIVM also provides a coordinated monitoring strategy, in which three monitoring vans, the National Radioactivity Monitoring Network (NMR) and eight contracted partner institutes play a key role. These partner institutes are the Nuclear Physics Cyclotron Institute in Groningen (KVI), the Technical University of Eindhoven (TUE), the Interuniversity Reactor Institute in Delft (IRI), the Netherlands Energy Research Foundation in Petten (ECN), KEMA in Arnhem, URENCO Netherlands B.V. in Almelo, DSM Research BV in Geleen, and EPZ, the proprietor of the nuclear power plant in Borssele (KCB). They are geographically more-or-less evenly distributed throughout the country, which provides the means for fast and reliable evaluation of the situation. ECN is also subcontracted to maintain the local gamma counters and workstations of the NMR and to operate a monitoring plane. TUE operates a monitoring van by agreement with RIVM. Figure 2 illustrates the general structure of the monitoring organisation coordinated by RIVM.

2. INTERNATIONAL COOPERATION, TRAINING AND EXERCISES AS A BASIS FOR ORGANISATIONAL IMPROVEMENTS

The organisation, developed after the Chernobyl accident, was the product of the experiences during this accident. Evaluation showed commitment to a common emergency management strategy at all levels and all relevant institutions to be a key factor for success. This conclusion still forms the main principle in the Dutch organisation for nuclear emergency management. The same principle serves as the basis for the development of a programme of cooperation with the neighbouring countries, Belgium and Germany. Regular exchanges of information and collective participation in exercises and cross-border activities should improve the coordination of monitoring strategies and model calculations to promote a coordinated effort during real emergencies.

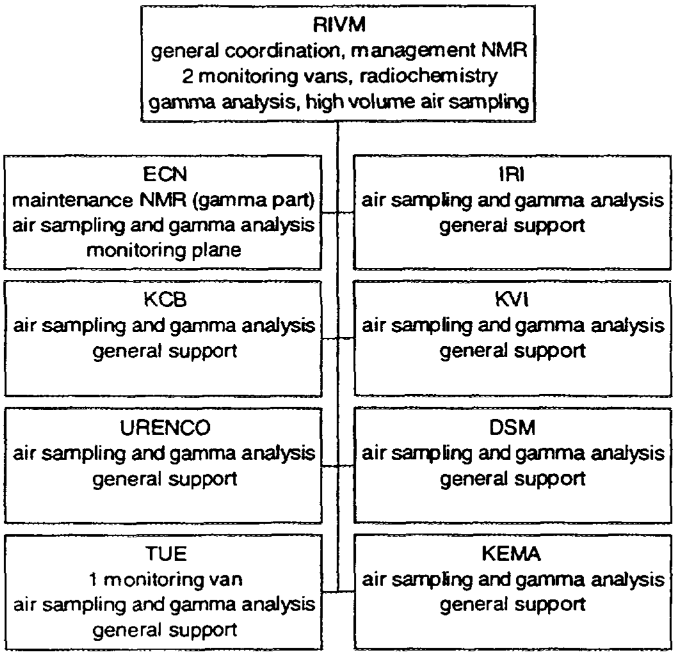

Fig. 2 Monitoring: RIVM and partner institutes.

An ambitious programme of training and exercises was developed to bring the new organisation up to standard. Since 1990 one or more exercises have been held yearly at the national level, with many participants and the involvement of many sections at the provincial and local levels, the regional fire brigades and the technical information organisation. Further, two technical exercises have already been organised in cooperation with colleagues from Belgium. These exercises do not only improve the overall preparedness, but also offer a basis for continuous general evaluation and fine tuning of the organisation [4].

One of the results of the evaluations has been the definition of a *core organisation*. This core organisation is operational in the first period of the accident when "direct" measures have to be taken. Such measures are directed at mitigating the dose that the population receives via the direct pathways of external radiation and inhalation. In this stage of the technical information and data collection, the use of model calculations and extrapolations, with possible application of a variety of "rule-of-thumb" approaches, prevails. It is expected that in a later stage improved source term and actual monitoring data will become available which may validate the first-stage results, and may reduce uncertainties in the evaluation of the situation and improve eventual dose assessments. This is parallelled by a gradual up-scaling of the organisation as the complexity of the situation increases or a situation develops where "indirect" measures (directed at the pathways food, drinking water etc.) are becoming more important.

The exercises have also shown the essential role of adequate communication facilities. It is the intention to provide all participants with access to an on-line information facility with a standardised graphical presentation module. In the PITER project a so-called Emergency Information System (EIS) is being tested for its performance in operational circumstances, both for nuclear and non-nuclear accidents. In developing the EIS instrument cooperation is sought with other European countries in the VISEC (Visualising ECURIE) project. These projects must act as a trigger for improved ways of graphical data exchange, thus enhancing efficiency and preventing unnecessary divergence at the European level.

3. INSTRUMENTATION

The available instrumentation involves the aforementioned monitoring vans and the monitoring plane, operational models for environmental dispersal and dose calculations, extensive laboratory facilities for gross and nuclide-specific analysis of radioactivity in air, water, soil and (food) products, and, since January 1996, the National Radioactivity Monitoring Network (NMR). This automated monitoring network is the result of an integration of the two monitoring networks for radioactivity in air in operation in the Netherlands. These networks each had a different goal and function. One network (LMR) was run by RIVM for the Ministry of Housing, Spatial Planning and Environment, the other (BMNI) was run by ECN on behalf of the Ministry of the Interior. Final integration was reached by the end of 1995, when extensive tests proved its full operationality. Figure 3 shows the NMR locations throughout the Netherlands. The integrated network, consisting of 280 gamma monitoring stations, 14 alpha/beta monitoring stations and two nuclide-specific monitors at the RIVM in Bilthoven, combines the qualities of both constituent networks. The general design and set-up of the NMR and its constituents are described in previous papers [5, 6]. The new set-up will lead to a further improved efficiency in detecting small but relevant variations in the radioactivity level in air.

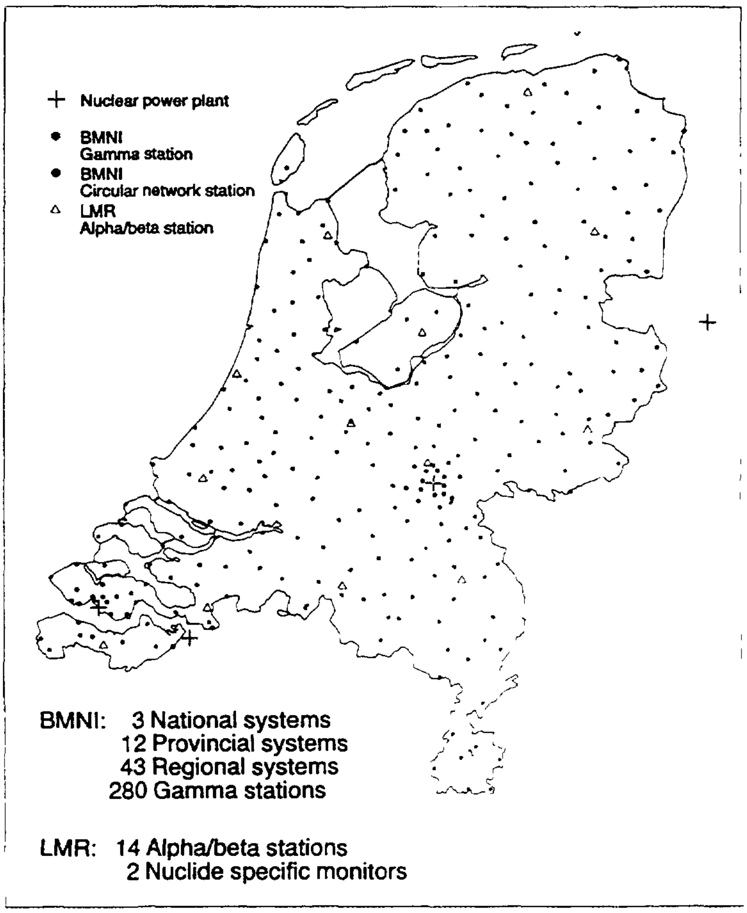

Fig. 3 The Dutch National Radioactivity Monitoring Network (NMR) and its constituents.

4. CONCLUSIONS

The preparedness for nuclear emergencies in the Netherlands has been improved, both at the organisational and the instrumental levels. Before the Chernobyl accident the organisation in the Netherlands was primarily focused on local incidents and relied for its functioning mainly on ad hoc decisions and personal expertise. Specific technical facilities were limited. The Chernobyl accident has led to a more decisive organisation that combines central management with the coordinated input of expertise from all levels and institutions. The present facilities include state-of-the-art modelling and monitoring techniques. Better information and communication equipment has become available. In recent years, a further evolution has taken place. Frequent training and information exchange, formulation of standard procedures and a coordinated default monitoring strategy provide a basis for an improved efficiency of government response to nuclear emergencies.

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POSSIBLE APPLICATION OF FUZZY THEORY TO THE HUMAN RELIABILITY ANALYSIS OF NUCLEAR ACCIDENT AT CHERNOBYL

XA9745901

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1 INTRODUCTION

There are many types of uncertainties involved in the risk assessment However, they may be divided into two major categories, the uncertainty due to randomness and that due to fuzziness Conventional methods of treating the uncertainty are to apply statistical methods of estimation which are, in turn, based on the concept of probability Even in the cases where the source of uncertainty is of a non-statistical nature, the formal application of statistical methods of analysis is often done to deal quantitatively with the uncertainty tacitly acccepting the premise that uncertainty - whatever its nature - can be equated with randomness Most of the works on risk analysis or safety assessment have been done using such methods In the fuzzy set concept some uncertainties are accepted as uncertain with the introduction of the membership function Instead of 'true or false' of the non-fuzzy two-valued logic, any intermediate value between zero (false) and one (true) can be assumed for membeship function in the fuzzy set theory

Fig 1 shows the branch of Chernobyl accident event tree in the order of the accident process report as an example and Fig 2 dependence between actions under diffeent assumptions In Fig 1, capital letters represent failure and small letters represent success Table 1 shows the human performance models and Table 2 the result of probabilistic analysis using the probabilistic method of Swain and Guttman's Handbook of human reliability analysis with emphasis on nuclear power plant applications and the result taking into consideration of the effect of the performance shaping factor which may be assumed for Chernobyl based on the INSAG-1 and Russian report [1-5] The human error probability of the accident sequence which would have been extremely unlikely to occur is increased by several orders of magnitude due to the effect of the performance shaping factors [4] In Fig 2 and Tables 1 and 2, ZD zero dependence, LD low dependence, HD high dependence and CD complete dependence The dependence in the Chernobyl accident is assumed as shown in Fig 2(a) [2]

2 RELIABILITY ANALYSIS BY ERROR POSSIBILITY

1 *Error possibility*

Let us consider a fuzzy set E on the interval [0, 1] associated with a possibility distribution $E(e)$ such as

$$E(e) = \frac{1}{1 + 20 \times |e - e_0|^m}, \qquad (1)$$

where $m = m_L$ for $e \leqslant e_0$ and $m = m_U$ for $e \geqslant e_0$ The parameter m is related to the fuzziness and e_0, called the center of E, gives the maximum grade of $E(e)$ The fuzzy set E is called 'error possibility' and e is called 'likelihood of error'. In this paper e_0 and m are assumed to be derived from the triplet of the error

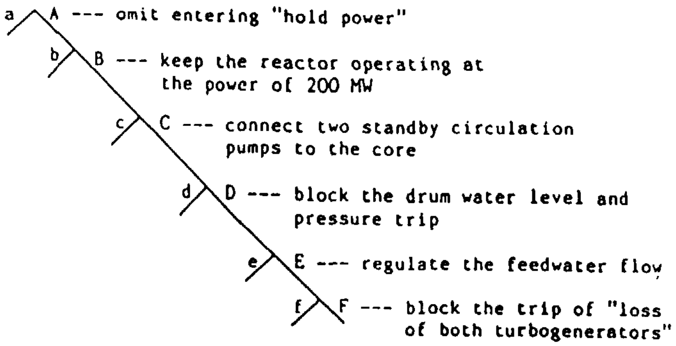


Fig. 1. Branch of Chernobyl accident event tree.

```
A-----B-----C-----D-----E-----F
   ZD    CD    HD    HD    HD
              (a)

A'----B'----C'----D'----E'----F'
   ZD    HD    LD    LD    LD
              (b)
```

Fig. 2. Dependence between actions under different assumptions.

Table 1. Human performance models

Item	Human errors and human error probabilities
1	Omitting a step or an important instruction from a formal or ad hoc procedure: $[6\times10^{-4}, 3\times10^{-3}, 1.5\times10^{-2}]$
2	Failure of administrative control in carrying out a plant policy or scheduled tasks: $[2\times10^{-3}, 1\times10^{-2}, 5\times10^{-2}]$
3	Modification of estimated human errors probabilities for the effects of very low stress level: $\times 2$
4	Equations for conditional probabilities of failure on task N given failure on previous task $N-1$ for different level of dependence $P_F(N \mid N-1 \mid ZD) = Er$ $P_F(N \mid N-1 \mid LD) = (1+19\times Er)/20$ $P_F(N \mid N-1 \mid MD) = (1+6\times Er)/7$ $P_F(N \mid N-1 \mid HD) = (1+Er)/2$ $P_F(N \mid N-1 \mid CD) = 1$ where Er represents the human error probability of task N

Table 2. The estimated human error probabilities

	Error	Type of error	Dependence	Human error probability
Fig. 2(a)	A	Omission	–	3×10^{-2} *
	B	Failure of administrative control	ZD	5×10^{-2} *
	C	Failure of administrative control	CD	1
	D	Failure of administrative control	HD	5.05×10^{-1}
	E	Failure of administrative control	HD	5.05×10^{-1}
	F	Failure of administrative control	HD	5.05×10^{-1}
Joint human error probability				1.9×10^{-4}
Fig. 2(b)	A'	Omission	–	3×10^{-3}
	B'	Failure of administrative control	ZD	1×10^{-2}
	C'	Failure of administrative control	HD	5.05×10^{-1}
	D'	Failure of administrative control	LD	5.95×10^{-2}
	E'	Failure of administrative control	LD	5.95×10^{-2}
	F'	Failure of administrative control	LD	5.95×10^{-2}
Joint human error probability				3.19×10^{-9}

* The median of the human error probability is used.

probability [Er_L, Er_M, Er_U], where Er_M is the recommended value of the error probability, Er_L is its lower bound and Er_U is its upper bound.

(i) e_0 is derived from Er_M:

$$e_0 = f(Er_M) = \begin{cases} \dfrac{1}{1 + (K \times \log(1/Er_M))^3}, & Er_M \neq 0, \\ 0, & Er_M = 0, \end{cases} \tag{2}$$

where K is a constant. Table 3 shows the classification of e_0.

Table 3. Classification of e_0

Class	Bounds of e_0	Representative value of e_0	Bounds of error probability
C_1	1.0	1 0	1 0
C_2	0.9–1.0	0 95	$7\ 830 \times 10^{-2}$–1.0
C_3	0 7–0 9	0 8	$1\ 841 \times 10^{-2}$–7.830×10^{-2}
C_4	0 5–0 7	0 6	$5\ 0 \times 10^{-3}$–1.841×10^{-2}
C_5	0 3–0 5	0 4	$8\ 872 \times 10^{-4}$–5.0×10^{-3}
C_6	0 2–0 3	0 25	2.225×10^{-4}–8.872×10^{-4}
C_7	0 1–0 2	0 15	$1\ 636 \times 10^{-5}$–$2\ 225 \times 10^{-4}$
C_8	0 05–0 1	0 075	$7\ 243 \times 10^{-7}$–$1\ 636 \times 10^{-5}$
C_9	0 0–0 05	0 025	0 0 –$7\ 243 \times 10^{-7}$
C_{10}	0 0	0 0	0 0

In accordance with [4], in this paper K is defined as

$$K = 1/\log(1/5 \times 10^{-3}). \tag{3}$$

(ii) m_L and m_U are derived from [Er_L, Er_M, Er_U] The parameters m_L and m_U are together rewritten as m.

(1) Define $k_L = Er_M/Er_L$ and $k_U = Er_U/Er_M$ The parameters k_L and k_U are together rewritten as k.

(2) Four uncertainty bounds are defined such as $k \leqslant 3$, $3 < k \leqslant 5$, $5 < k \leqslant 10$ and $10 < k$. For these uncertainty bounds we refer to Table 4 [4].

(3) In the class C_5 define $m = 2.0$ for $k \leqslant 3$, $m = 2.5$ for $3 < k \leqslant 5$, $m = 3.0$ for $5 < k \leqslant 10$ and $m = 3\ 5$ for $10 < k$, respectively

Let e_{0i} be the representative value of e_0 in the class C_i and E_i be the error possibility in the class C_i such as $E_i(e_{0i}) = 1$ ($i = 2, 3, \ldots, 9$).

(4) Within the same uncertainty bounds the parameter m is obtained so as to satisfy

$$E_i(e_i) = E_5(e_5), \quad i = 2, 3, \ldots, 9, \tag{4}$$

where $e_i = f(10 \times Er_{Mi})$ when m_U is obtained, $e_i = f(Er_{Mi}/10)$ when m_L is obtained, and $e_{0i} = f(Er_{Mi})$

Table 5 shows the result obtained by the above procedure. However the boldface values are used by referring to Table 4 The parameter m for $10 < k$ is used when the error probability of a given task is assumed to be fuzzier.

The error possibility in the class C_1 is defined as

$$E(e) = \begin{cases} 1, & e = 1, \\ 0, & e \neq 1, \end{cases} \tag{5}$$

and that in the class C_{10} is defined as

$$E(e) = \begin{cases} 0, & e \neq 0, \\ 1, & e = 0. \end{cases} \tag{6}$$

Table 4. General guidelines for estimating uncertainty bounds for estimated error probability

Error probability	Lower bound	Upper bound
0.01 < Er	Er/5	2 × Er–5 × Er
0.001 < Er < 0.01	Er/3	3 × Er
Er < 0.001	Er/10	10 × Er

Table 5. Parameter m

Class	m	$k \leq 3$	$3 < k \leq 5$	$5 < k \leq 10$	$10 < k$
C_2	m_U	2.7	3.3	4.0	4.7
	m_L	2.7	3.3	4.0	4.7
C_3	m_U	1.3	1.7	2.0	2.3
	m_L	3.1	3.8	4.6	5.4
C_4	m_U	1.9	2.4	2.9	3.4
	m_L	2.6	3.3	3.9	4.6
C_5	m_U	2.0	2.5	3.0	3.5
	m_L	2.0	2.5	3.0	3.5
C_6	m_U	1.6	1.9	2.3	2.7
	m_L	1.5	1.9	2.3	2.7
C_7	m_U	1.1	1.4	1.7	1.9
	m_L	1.2	1.5	1.8	2.1
C_8	m_U	0.8	1.0	1.1	1.3
	m_L	0.9	1.1	1.4	1.6
C_9	m_U	0.5	0.6	0.7	0.9
	m_L	0.7	0.8	1.0	1.2

2. *Logical connectives of error possibilities*

Two tasks are assumed to be independent of each other.

(i) AND connective.

The function F is used as the 'AND connective' of error possibilities:

$$F(x, y) = \frac{1}{1 + \{((1-x)/x)^{1/3} + ((1-y)/y)^{1/3}\}^3}, \quad 0 < x, y \leq 1, \tag{7}$$

where $F(0, 0) = F(x, 0) = F(0, y) = 0$.

Parallel tasks are connected by an 'and gate' in a fault tree. The error possibilities of parallel tasks are operated by the 'AND connective' and the extension principle in order to obtain the error possibility of the whole task.

(ii) OR connective.

The function G is used as the 'OR connective' of error possibilities:

$$G(x, y) = \frac{\{(x/(1-x))^3 + (y/(1-y))^3\}^{1/3}}{1 + \{(x/(1-x))^3 + (y/(1-y))^3\}^{1/3}}, \quad 0 \leq x, y < 1, \tag{8}$$

where $G(1, 1) = G(x, 1) = G(1, y) = 1$.

Series tasks are connected by an 'or gate' in a fault tree. The error possibilities of series tasks are operated by the 'OR connective' and the extension principle in order to obtain the error possibility of the whole task.

3. *Dependence between consecutive tasks*

Only the dependence between parallel tasks as shown in Figure 3 is introduced. The dependence between series tasks may be found in [3], but it is not considered in our case study. It is assumed that the task B is performed after the task A is done. If a human operator fails in the task A, then he is apt to fail in the task B. If he succeeds in the task A, then he is also liable to succeed in the task B. However if he succeeds in the task A, he succeeds in the whole task whether he succeeds or not in the task B. So it is not necessary to consider the latter case.

Let E_A be the error possibility of the task A, E_B be that of the task B and R be the fuzzy causal relation representing the dependence.

(i) The case that the error of the task A influences the error of the task B.

Let E'_B be the error possibility of the task B influenced by the error of the task A. Under logical consideration, E'_B can be estimated as 'E_A AND R'. In this case E'_B is the error possibility of the whole task:

$$E'_B = F(E_A, R). \tag{9}$$

(ii) The case that the error of the task A does not influence the error of the task B.

The portion of the error possibility of the task A which does not influence the error of the task B is obtained by

$$E_A = G(E'_A, E'_B), \tag{10}$$

where E'_A is this portion.

The error possibility of the whole task E' in this case is obtained by

$$E' = F(E'_A, E_B). \tag{11}$$

(iii) The error possibility E as a whole.

The error possibility E is obtained by

$$E = G(E', E'_B). \tag{12}$$

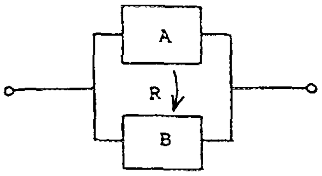


Fig. 3. Dependence between parallel tasks.

4. *Evaluation*

Let $(E)_\alpha = (e_1(\alpha), e_2(\alpha))$ be an α-cut of E.

(i) The center e_0 of E:

$$J1 = e_0. \tag{13}$$

(ii) Potentiality for error. Define

$$J2 = \frac{\int_0^\beta (e_2(\alpha) - 0.5)\alpha \, d\alpha}{\int_0^1 (1 - 0.5)\alpha \, d\alpha}, \tag{14}$$

where $e_2(\beta) = 0.5$. $J2$ is evaluated when $J1 \leqslant 0.5$.

(iii) Fuzziness of error possibility. Define

$$J3 = \frac{\int_0^1 (e_2(\alpha) - e_0)\alpha \, d\alpha}{\int_0^1 (1 - e_0)\alpha \, d\alpha}, \tag{15}$$

where $e_2(\alpha) \geqslant e_0$ for $\alpha \in [0, 1)$.

(iv) The relative potentiality and the relative fuzziness. Define

$$J2' = \frac{\int_0^{\beta} (e_2(\alpha) - 0.5)\alpha\, d\alpha}{\int_0^{\beta'} (e_2'(\alpha) - 0.5)\alpha\, d\alpha}, \tag{16}$$

where $e_2'(\beta') = 0.5$, and

$$J3' = \frac{\int_0^{1} (e_2(\alpha) - e_0)\alpha\, d\alpha}{\int_0^{1} (e_2'(\alpha) - e_0)\alpha\, d\alpha}. \tag{17}$$

The denominators in Eqs. (16) and (17) are the evaluation of the standard error possibility E' in the class which e_0 belongs to. Let $(E')_\alpha = (e_1'(\alpha), e_2'(\alpha))$ be an α-cut of E'. The standard error possibility E' has the following possibility distribution

$$E'(e) = \frac{1}{1 + 20 \times |e - e_0|^m}, \tag{18}$$

where e_0 is the evaluation $J1$ and m is the value in the class which e_0 belongs to The parameter m is determined by Table 5.

Equations (16) and (17) imply the relative evaluation in the class which e_0 belongs to The potentiality and the fuzziness of E are compared with those of E'

3 RELIABILITY ANALYSIS OF CHERNOBYL ACCIDENT

In this section the reliability analysis on the Chernobyl accident is performed by using error possibility and the result is compared with the result of the probabilistic analysis The triplet of the human error probability for the derivation of the error possibility is the same as the one used in the probabilistic analysis That is, the triplet of the human error probability of 'A' is $[6 \times 10^{-4}, 3 \times 10^{-3}, 1.5 \times 10^{-2}]$ and the triplets of the human error probabilities of the other tasks are each $[2 \times 10^{-3}, 10^{-2}, 5 \times 10^{-2}]$ The modification by the stress factor is performed in Figure 4(a)

Figures 4(a) and 4(b) show the fault trees which correspond to Figures 2(a) and 2(b), respectively Figure 5 shows the fuzzy causal relations in this analysis Figures 6(a) and 6(b) show the error possibilities of the top events in the fault trees shown in Figures 4(a) and 4(b), respectively The subscript 1 is given to the result in Figure 6(a) and the subscript 2 is given to the result in Figure 6(b)

Comparing the result of the fuzzy analysis and that of the probabilistic analysis the following is considered

(1) $J1_1 > J1_2$ This result is inferred by the result of the probabilistic analysis

(2) $E_1(0) < E_2(0)$ This implies that it is less possible for the human operator to make an error in the case of Figure 4(b) than in the case of Figure 4(a)

(3) $E_1(1) > E_2(1)$ This implies that it is more likely for the human operator to make an error in the case of Figure 4(a) than in the case of Figure 4(b)

Human reliability in Figure 4(a) becomes much lower than that in Figure 4(b) due to the effect of the performance shaping factors as mentioned before However, a small error probability does not necessarily mean a low possibility to make an error This consideration is found by the following

(4) Though $J1_2$ is small, $J2_2$ and $J3_2$ are not so small. This result shows that the potentiality for error is not low and that $J1_2$ is not evaluated with confidence. That is to say, small $J1$ does not always imply good reliability.

(5) $J2_2' > J2_1'$ and $J3_2' > J3_1'$ in spite of $J1_1 > J1_2$, $J2_1 > J2_2$ and $J3_1 > J3_2$ This also shows that small $J1$ does not always mean good reliability.

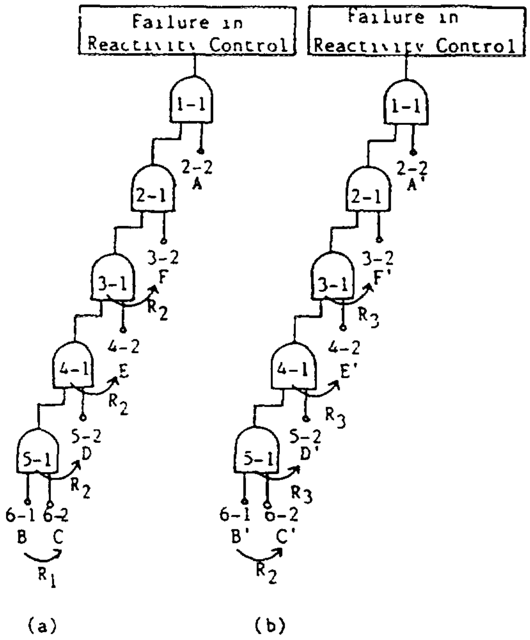
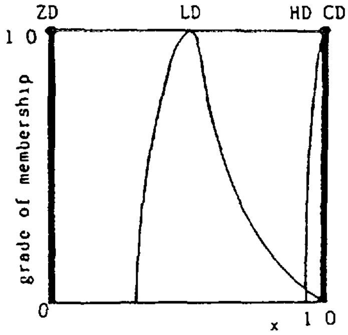


Fig 4 Fault trees



$$\text{CD} \quad R_1(x) = \begin{cases} 1, & x = 1.0, \\ 0, & 0.0 \le x < 1.0, \end{cases}$$

$$\text{HD} \quad R_2(x) = \begin{cases} 1 - 400(x-1)^2, & 0.95 \le x \le 1.0, \\ 0, & 0.0 \le x < 0.95, \end{cases}$$

$$\text{LD} \quad R_3(x) = \begin{cases} 4(1-x)^2, & 0.6 \le x \le 1.0, \\ 1 - 36(x-0.5)^2, & 0.5 \le x < 0.6, \\ 1 - 25(x-0.5)^2, & 0.3 \le x < 0.5, \\ 0, & 0.0 \le x < 0.3, \end{cases}$$

$$\text{ZD} \quad R_4(x) = \begin{cases} 0, & 0.0 < x \le 1.0, \\ 1, & x = 0.0 \end{cases}$$

Fig 5 Membership functions of fuzzy causal relations

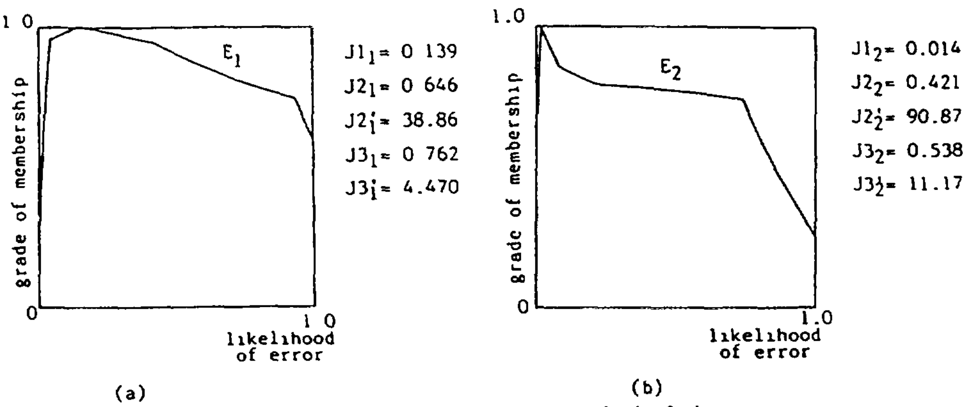


Fig 6 Error possibilities of the top events in the fault trees

(6) $J2_1$ and $J3_1$ as well as $J1_1$ are large. This result shows that the potentiality for error is high. However large $J3$ does not necessarily yield with confidence that the human operator makes an error certainly.

If $J2$, $J3$, $J2'$ and $J3'$ are also evaluated, the following result is obtained: Reliability in Figure 4(b) is not necessarily much better than that in Figure 4(a). Figure 6(b) shows that the human operator has enough possibility to make an error. There is room for improvement of the management and administrative control system even in the case of Figure 4(b).

It is found that error possibility can be interpreted from many points of view. It is difficult to gain such an interpretation in probabilistic analysis.

4. DISCUSSION AND CONCLUSION:

This paper compared the result of fuzzy reliability analysis using error possibility with that of probabilistic analysis on the Chernobyl accident. This case study showed the following validity of fuzzy reliability analysis: error possibility can be interpreted from many points of view and it is difficult to gain such an interpretation in probabilistic analysis. The belief that a small error probability shows good reliability is dangerous in reliability analysis. Some big accidents have shown this consideration . This paper shows that it is necessary to apply fuzzy theory to reliability analysis. In INSAG-7, various possible other cases are discussed [6]. However, when the possibility of human error, human intervention or sabotage, whether it may be in operational stage or design stage or construction stage is involved, the analysis with error possibility based on fuzzy theory would be more important.

The additivity, based on which probability theory is developed, may not hold when human factors or human judgements are involved. Even if the error probability estimated by probabilistic method appears to be negligibly small, the possibility may not necessarily be small. If the possibility is small, the probability would also be small, but not vice versa. As long as the possibility is significant, the accident must be assumed to occur, even if the apparent probability is small. In other words, in order to ensure safety, possibilistic analysis with fuzzy theory would be more important than the probabilistic analysis, especially when human factors or human interventions are involved.

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INFLUENCE OF THE AFTERMATH OF THE CHERNOBYL ACCIDENT ON THE DESIGN OF A METHODOLOGY FOR THE DEVELOPMENT OF AN INTEGRATED ACCIDENT MONITORING SYSTEM

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Влияние последствий Чернобыльской аварии на формирование методологии развития интегрированной система мониторинга аварийных ситуаций

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Научно-производственное объединение "Тайфун"

Уроки Чернобыльской аварии привели к необходимости пересмотреть некоторые аспекты концепции мониторинга аварийных ситуаций. Анализ последствий показал, что наличие к моменту аварии развитой, в современном понятии этого слова, системы радиационного мониторинга позволило бы значительно смягчить воздействие аварии на население и природную среду, особенно в ее ранней стадии.

Развитие современной методологии мониторинга аварийных ситуаций, в том числе обусловленных радиационным фактором, должно исходить из понимания тесной взаимосвязи между опасными природными явлениями и техногенными авариями, последствия которых могут привести к экологическим катастрофам. Все виды катастроф создают единую замкнутую систему, в которой повышение вероятности развития одного вида опасностей ускоряет проявление других видов. Примером могут служить опасные явления (смерчи, пожары и др.) на территориях, загрязненных в результате Чернобыльской и других радиационных аварий, итогом действия которых становится дальнейшего распространение радиоактивного загрязнения окружающей среды со всеми вытекающими отсюда последствиями.

Постоянное увеличение числа синергетических или многоступенчатых катастроф, когда опасные природные явления вызывают технические катастрофы, которые, в свою очередь, часто приводят к резкому ухудшению экологической обстановки заставляет специалистов стремиться к идее создания единой системы мониторинга опасных явлений.

Развитие таких катастроф значительно усложняет принятие мер по их ликвидации, поскольку профилактические меры, направленные на предупреждение опасных природных явлений, оказываются неадекватными в случае совместного развития бедствий природного и техногенного характера. Аварии в современной техносфере по своим масштабам и тяжести последствий сравнимы уже с природными катастрофами, а потому перестают быть "национальным достоянием" отдельно взятых государств и требуют совместных действий всего мирового сообщества по обеспечению защиты населения и природной среды.

Корректный выбор и своевременное применение адекватных контрмер могут значительно снизить ущерб в условиях аварийной ситуации. Для выбора эффективных контрмер лица принимающие решения (ЛПР) должны учитывать разнообразные характеристики, определяющее специфику и условия развития аварийной ситуации. Характеристики аварийной ситуации могут изменятся как результат применения контрмер, что делает задачу ЛПР еще более трудной. В такой ситуации практически невозможно принять разумное решение без постоянно действующей системы мониторинга и специальных средств информационной поддержки, а учитывая международный характер проблемы - объединенной системы мониторинга и единой компьютерной технологии информационной поддержки принятия решений.

Таким образом реализация интегрированной системы мониторинга опасных явлений возможна только при условии создания единой международной информационной инфраструктуры, включающей систему наблюдения, сбора и обработки данных. В рамках такой инфраструктуры становится возможной разработка теории и практических методов обеспечения безопасности в рамках распределенной системы поддержки принятия решений.

Вопросам реализация этих важных и своевременных идей в практике работы Федеральной службы России по гидрометеорологии и мониторигу загрязнения окружающей среды (Росгидромет) посвящен данный доклад.

В структуре Росгидромета, создается интегрированная система оперативной оценки и прогноза состояния загрязнения природной среды при аварийных ситуациях техногенного характера. Детальное знание гидрометеорологических условий при тех или иных авариях - необходимый компонент этой системы. Поступающую для этих целей в Оперативный (кризисный) центр Росгидромета гидрометеорологическую информацию, циркулирующую по каналам связи, кроме того планируется использовать для создания постоянной системы мониторинга опасных природных явлений. Разрабатываемую же совместно с концерном Росэнергоатом Министерства РФ по атомной энергии и рядом западноевропейских организаций (в рамках проекта RODOS Европейской комиссии) интегрированную систему поддержки принятия решений при ядерных авариях предполагается дополнить подобной системой при природных опасных явлениях и создать основу для развития в перспективе единой системы мониторинга и раннего предупреждения аварийных ситуаций техногенного и природного происхождения.

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ENSURING RADIATION SAFETY DURING CONSTRUCTION OF THE FACILITY "UKRYTIE" AND RESTORATION OF UNIT 3 OF THE CHERNOBYL NUCLEAR POWER STATION

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INTRODUCTION

On April 26, 1986, an accident at the fourth power unit of the Chernobyl NPS (ChNPS) destroyed the reactor core and part of the power unit building, whereby sizeable amounts of radioactive materials, stored in reactor at operation, were released into the environment, and there were also highly active fragments of fuel elements and pieces of graphite from reactor spread on ChNPS site near to safety block.

Information on the accident at ChNPS, including its cause and consequences, was considered at special meeting conducted by IAEA on August 25-29, 1986, in Vienna [1]. In final report of International Advisory Group for Nuclear Safety (IAGNS), prepared by results of meeting activities, the main stages of the accident effects elimination (AEE) immediately on the station site according to the data, received before August 1, 1986 [2], were discussed.

In 1987-1990 the published materials on the later period of AEE, completed by building "Ukrytie" installation at the fourth power unit of ChNPS [3-7].

1. THE PURPOSE OF "UKRYTIE" INSTALLATION

After the urgent tasks in initial stages of AEE, had been solved, made a decision for a prolonged conservation of the safety block. It was due to a required prevention of radioactive materials release from the destroyed unit into the environment and penetrating radiation protection of NPS territory. It was necessary also to control the behaviour of destroyed reactor fuel mass and provide a possibility to influence undesirable processes.

The task to bury the destroyed power unit was difficult and unique, as had no analogues in the world engineering practice. The difficulty of installation construction apart from considerable destruction of the fourth power unit building was to a great extent intensified by a complicated radiation situation in the zone of unit destruction, that made it difficult of access and limited extremely the use of engineering decision (fig. 1).

Radio prospecting conducted in the region of destroyed unit in preparatory period (end of May-beginning of June 1986) showed that the main factor, defining the radiation situation by "Ukrytie" construction, was Y-radiation whose dose rate constituted from hundreds of mR/h to hundreds of R/h (1 R = 2,58 10-4 C/kg, 1 R/h = 7,17 10-8 A/kg) and on individual spots with the fragments of reactor core elements it came to thousands of R/h. Surface contamination of territory and NPS building made up from 10e4 to 10e8 of alpha-particles/(cm2min) and from 10e2 to 10e5 of alpha-particles/(cm2min) [6].

The main problems that were to be solved when choosing design decisions for "Ukrytie" installation reduced to the following:

1.1. The installation by its purpose was neither a burial-ground of radioactive waste, nor a storage for nuclear fuel, but should be an operated installation where the following processes are controlled and excluded:

- chain fission reaction development;
- breakdown of heat removal from fuel residue that would result in its melting;
- formation of explosive concentration of radiolytical hydrogen.

1.2. It was necessary to minimize the time of installation construction to reduce the destroyed reactor influence on the environment and NPS site that would allow to resume the operation of shut down power units in short time.

1.3. The installation construction should be carried out with minimum remaining of builders and erectors in radio hazardous conditions to decrease personal and collective exposure doses.

1.4. There was to provide a sufficient strength and reliability of building structures, using, if possible the undamaged elements of power unit building, and to preserve the functions of installation affected by different natural phenomena (atmospheric precipitation, hurricanes, etc.).

2. ORGANIZATIONAL-TECHNICAL MEASURES PROVIDING "UKRYTIE" BUILDING

To overcome such a complicated problem a specialized organization - Management of construction N 605 (MC-605) was formed on May 20, 1986. This powerful building organization consisted of several building areas intended to erect different members of "Ukrytie", of erecting area, concrete - mixing plants and management of mechanization and motor transport, power

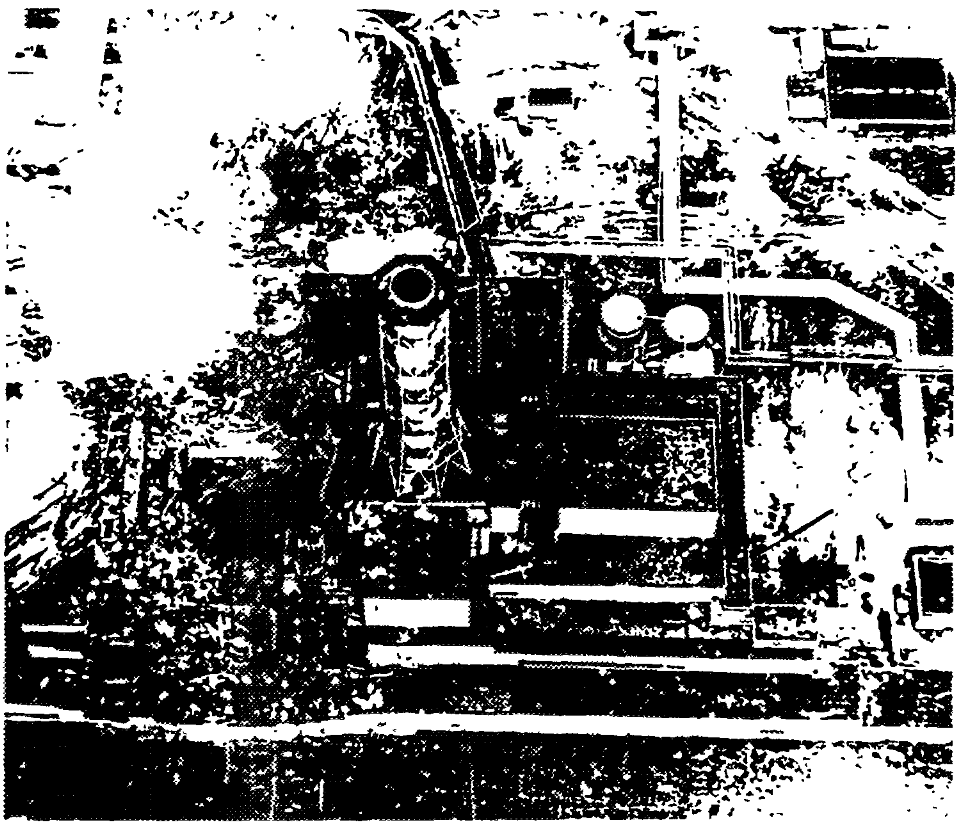

Fig .1.A view overlooking Chernobyl NPS

supply, production-technical delivery as a complete plant. MC-605 included as components the Office of radiation monitoring (ORM), supply services, including canteens, logistics, medical - household supply as well as centers for personnel living [8]. MC-605 subdivisions were stationed immediately in ChNPS territory, in Chernobyl and Ivankovo cities and on "Teterev" railway station of Kiev region. Living bases and subsidiary services were located 50-100 km away from the working place. In view of complicated radiation situation and a need for following radiation safety standards and regulations a watch method of personnel activities with a watch duration of 2 months was set up. The size of a single watch came to 10,000 persons, the personnel was working in ChNPS territory for 24 hours in 4 shifts.

The designers examined 18 design alternatives of "Ukrytie". In final subsequently realized alternative the most use as installation "Ukrytie" supports was made of undamaged and partially destroyed structures of the power unit. This decision allowed to considerably reduce the construction time and decrease the consumption of building materials.

The chosen design was an original solid-spatial structure formed by three cascade - rising blocks (12 m high) on the main tumble side (northern), by monolithic concrete wall reinforced with metalwork provided with buttresses on the

undamaged side (western); undamaged structures with supplementary supports in tumbles and ceiling with metal beams (70 m long) were used on inner sides (eastern and southern) (fig. 2, 3). Making of ceiling for the fourth reactor central room presented the greatest difficulty, it was provided by mounting a special construction in the form of bridge made of two parallel metal beams. The remaining part of "Ukrytie" installation consisted of separate walls: concrete wall - between the third and the fourth power units (making the most use of walls available) and hermetically sealed metal one - between the second and the third power units.

Implementation of design decisions while constructing "Ukrytie" installation became possible in complicated radiation situation like this due to a package of suitably developed organization - technical measures including radiation shielding actions which involve the following:

2.1. Wide employment of construction equipment and remotely controlled machines including operation by radio and television. To control the erection process a central operations post, provided with video cameras, was set up, connected by a communication system to remote mobile video cameras, assembled directly on crane booms and special towers, installed in places of maximum view(fig. 4). Similarly, by means of video monitors and two-way loudspeaker communication the work was organized in places of increase radiation levels (over 10 R/n).

2.2. Development of special technologies of concrete work production with remote

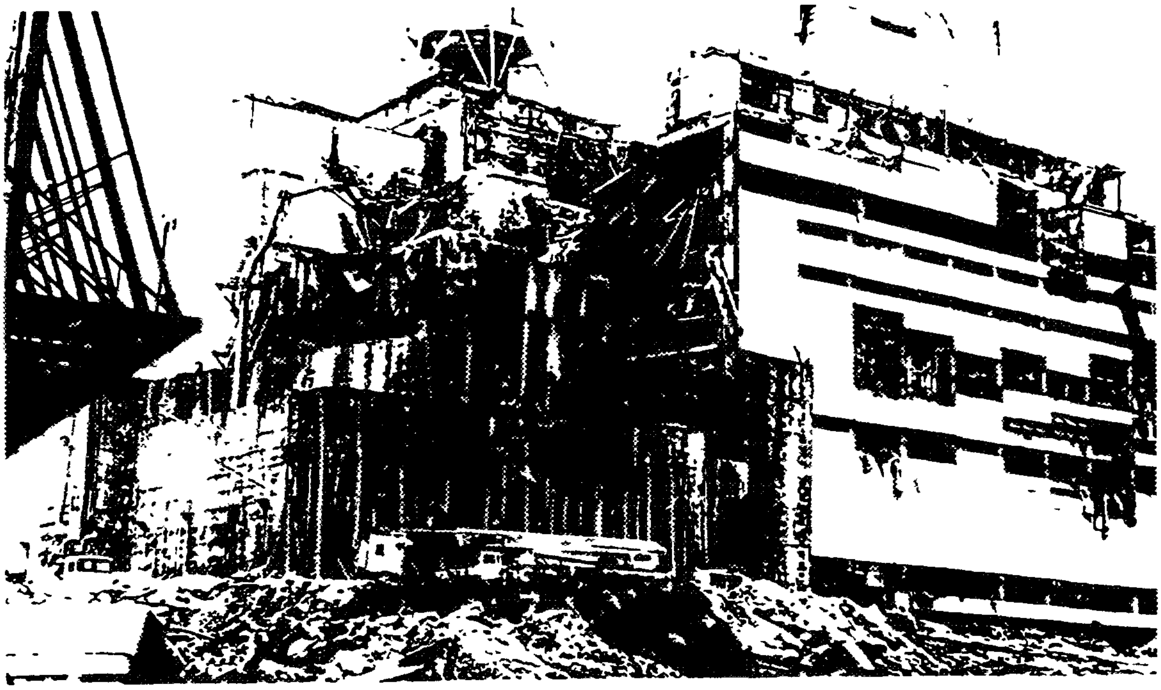

Fig. 2. A view of Chernobyl NPS at the engine room side

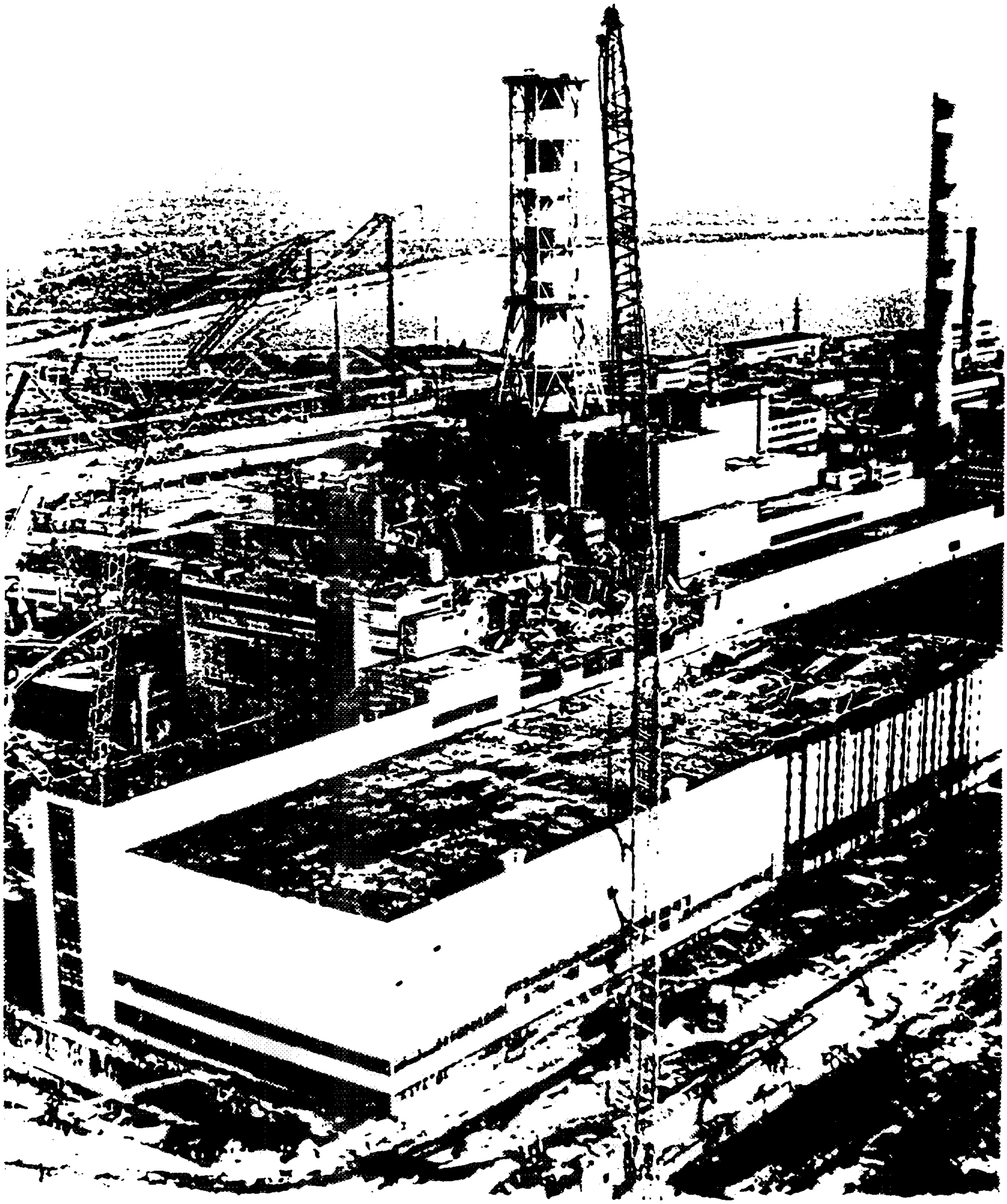

Fig. 3.Building of cascade wall

Fig. 4.Screens for remote job monitoring

employment of concrete pumping technique and different methods of concrete mix retardation using metal and nylon nets, beds with concrete or crushed stone and so on, as well as remote reinforcement of undamaged structures(fig. 5).

2.3. Development and employment of different radiation protected machines and devices and screens for operations in fields of radiation from units to hundreds of roentgen per hour whose radiation protection coefficients were 5-3000 [9].

2.4. Development and introduction of technologies and technical facilities of mechanical decontamination of ChNPS territory and constructions. The basic part of territory around the destroyed unit was decontaminated by removing the scattered active elements and skimming the contaminated ground surface layer; in individual places the dust suction was produced, suppression of local sources was performed by crushed stone filling and concreting. The total coating thickness was about 0,5 m, in some places it reached 1,5 m. The skimmed ground, rubbish and break-down components were taken away and collected in burial places - expressly provided "burial-grounds". For this purpose a store of technical facilities was used: engineer vehicles for removal of obstacles (EVRO-I) radio-controlled bulldozers DT-250, "Komatsu"

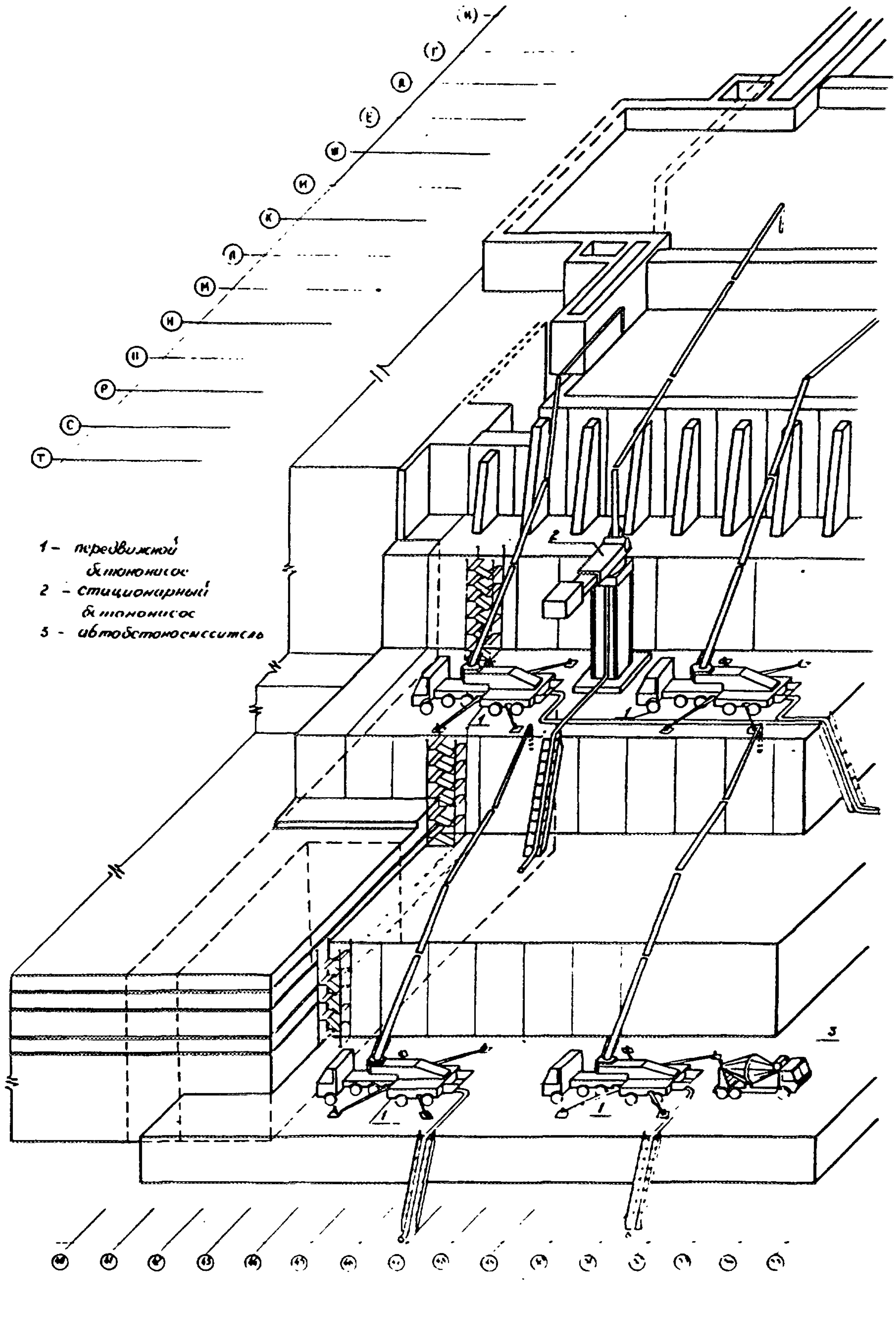

Fig. 5.Scheme of conreting of cascade wall

(Japan), front-end loaders of PPR and "Toro" corporation (Finland) make and other road-making machinery, provided with biological shielding of operators working place, air filtering units and television observation apparatus and radio communication.

To deactivate contaminated roofs robotized remote - controlled PP, TP, CTP, "Mobot-4" and MF-2, MF-3 (FRG) devices were used as well as radiation - protected mini tractors provided with either bulldozer blade, cutters or clamp-hooks.

2.5. Erection involved employment of "Demag" and "Libherr" (FRG) corporations. Cranes of great lifting capacity, which were equipped with video cameras and allowed to mount structural elements up to 160 t in mass on crane booms with radius of operation to 50 m. New methods of slinging and unslinging constructions without man's participation as well as special-purpose jigs to provide fine fit of constructions were introduced [4, 9].

Radiation protection of personnel consisted in restricting the time of being in radiation dangerous conditions, in remote executing the technological operations and employing protective screens and covers (shelters). The time of personnel transportation to the working area by means of lifts or elevators was reduced if possible; to get the workers of MC-605 through ChNPS territory the buses provided with lead screens (with protection coefficient of 3) and filters to purify the air entering the saloon were used; some buses were provided with air-conditioners.

The principle of distance protection was realized using instruments and devices holding a person away from local radiation sources (grips, manipulators, long handles). Walls of bags with sand, armored concrete slabs, lead bricks and temporary blinds made of sheet lead and mounted on portable frames were widely used as screens apart from those mentioned above.

3. MC-605 RADIATION SAFETY SERVICE MANAGEMENT

To organize radiation monitoring activities on work sites and living locations of MC-605 personnel, to check for their exposures and to provide protective measures for those involved in the accident elimination, the office of radiation monitoring (ORM) was established as part of MC-605, under MC-605 chief engineer assistant for radiation safety.

The structural division of MC-605 ORM is shown schematically in fig.6. The ORM included three laboratories: operations monitoring, everyday life monitoring, radiometry and equipment maintenance, and a support team. The office was staffed with skilled experts in monitoring and personnel protection against ionizing radiation.

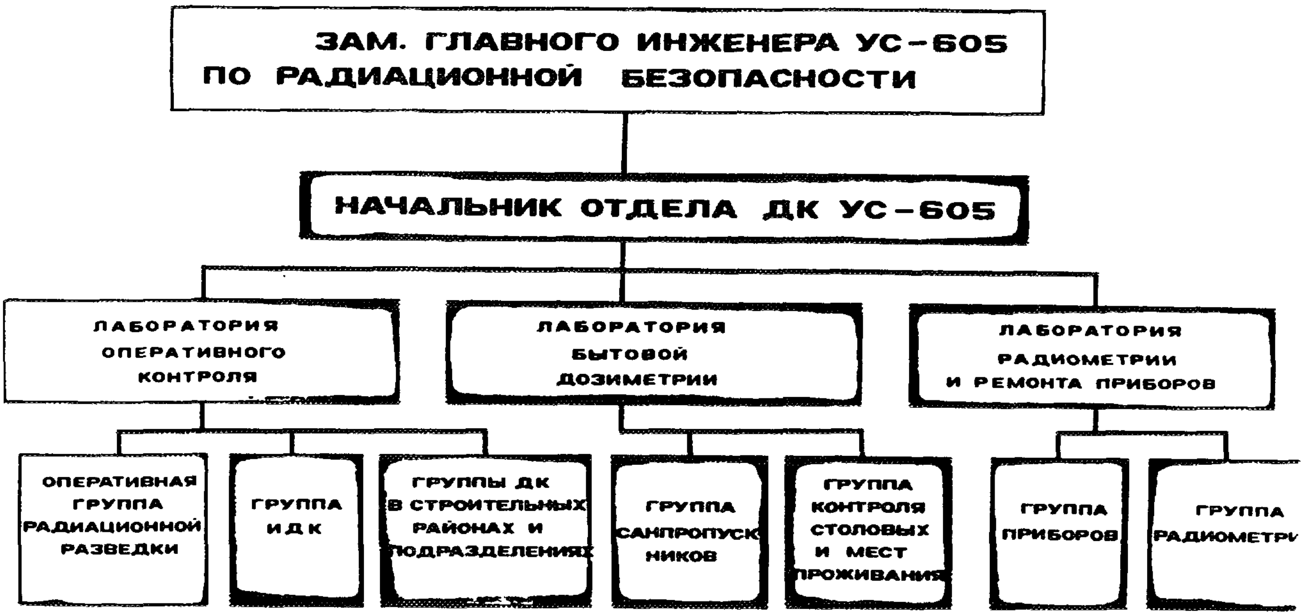

Fig. 6.Office radiometric monitoring organization chart

The total ORM force was 150 to 270 at various stages of MC-605 activities, 40 to 50 percent of these being engineers and technicians, others-monitoring laboratory assistants.

The operations monitoring laboratory consisted of groups as follows: operational radiation survey, monitoring of MC-605 locations and divisions (each location or division was assigned to a separate group), and personal monitoring. The laboratory had the following basic tasks:

- radiation surveys and mapping the radiation fields in ChNPS area and on the work sites related with the "Ukrytie" installation, to develop specific design concepts and schedules of installation works and also to provide radiation protections for the personnel;

- personnel exposure monitoring, including operational (e.g. for a shift, operation) and overall (e.g. for single operating cycles or for the whole period of watch activities), computer processing of monitoring data, and provision of information or reports on exposure levels;

- determination of actual efficiency of measures taken to protect personnel using shielding cabins and equipment, when radiation sources had been eliminated and suppressed with area, indoors and equipment decontaminated.

The laboratory of everyday life monitoring included groups for sanitation stations and inspections of canteens and residence locations. The basic tasks were: to monitor levels of gamma-radiation and contamination of personnel overalls, footwear, personal protective means and skin at sanitation stations, in canteens, hostels and other MC-605 public facilities, and also furniture and materiel surfaces; to check for contamination of vehicles and equipment departing from within the 30-km zone.

The laboratory of radiometry and maintenance consisted of groups for radiometry and equipment maintenance. Its primary tasks were:

- sampling, radiometric and spectrometric analyses of air, water, soil, vegetation samples and "smears" taken on construction sites, in MC-605 public, catering and residence facilities;

- maintenance, adjustment and calibration of monitoring and radiometry equipment employed by ORM, installation and adjustment of multichannel systems for remote monitoring of the radiological situation on individual sites of the "Ukrytie" installation.

The ORM activities were run according to certain regulations and the available programs and schedules of radiation monitoring efforts. The office structural division together with the instrumentation and methodology involved made it possible to carry out adequate monitoring as required by "Basic sanitary regulations... BSR-72/80" [10] taking into account the actual radiological situation in ChNPS area and others [6].

4. RADIATION MONITORING RESULTS

Radiation monitoring was carried out using techniques stated in [11,12] and techniques worked out as applied to a specific situation at the Chernobyl NPS: determination of spatial-angular distribution of gamma-radiation, searching for local sources of radiation, etc. These measurements were carried out using standard equipment (DP-5B, SRP-68) or dosimeters (ICS-A, DPG-03) with a set of different collimators developed at ORM [13].

One of the techniques intended for obtaining data on dominating sources in spacer was used in the territory of the Chernobyl NPS in June-July 1986. An armored troop-carrier was used as a "collimator", on its sides (front-back, left-right side, top-bottom) there were attached dosimeters ICS-A. A steel body and a lead shielding of the armored troop-carrier ensure (from every face of six sides) the measurement of a cumulative dose from corresponding half-space. It allows with an angular resolution of 2π radian to determine the main sources groups giving an estimation of their relative contribution into the dose rate.

The measurements showed that 75-80% of EDR radiation was attributed the fuel scattered on the territory surface, rather than "streaming" from the reactor break-down (this opinion was asserted from the first days of the accident at the Chernobyl NPS). In this connection the ORM proposed to build a protective shield by covering the territory adjacent to the 4 Unit with crushed rock (30 cm) followed by filling it up with concrete (30 cm). Implementation of these proposals caused the EDR reduction by a factor of 7-20 (from 180-430 R/h to 10-25 R/h).

Prospecting in dangerous places and in those which are difficult of access required the instruments modification: the cable connecting detectors with a test desk were elongated (to 15-20 m), time constant of the device pointer setting (for time measurement reduction in the fields with high EDR levels) was decreased, detectors were equipped with the rods which allowed the detector to be carried out at 3-4 m. After modification, the instruments were calibrated with sources-standards. The instruments used for remote (up to 300 m) monitoring of gamma-radiation EDR were modified as well.

Air radio nuclide concentration (sampling points are given in fig. 7) was determined using the aspiration method by air sampling on to AFA-RMP-20 filters followed by radiometric and spectrometric analysis of the samples from the filters.

Personal monitoring (PM) was performed by means of dosimeters-accumulators (ICS-A or DPG-03), all the workers of MC-605 were supplied with them. For operative exposure monitoring the staff was supplied with dosimeters D-2 (D-2P) on their working places, while receiving the task a work. Dose recording with D-2 was performed every shift or with every operation, that is several times for a shift.

Already at the initial stage of PM it was observed a divergence of dosimeters ICS-A (DPG-03) and D-2 (D-2P) reading. Monitoring results analysis showed that under identical exposure conditions at the Chernobyl NPS dosimeters D-2 and ICS-A readings differed by a factor of

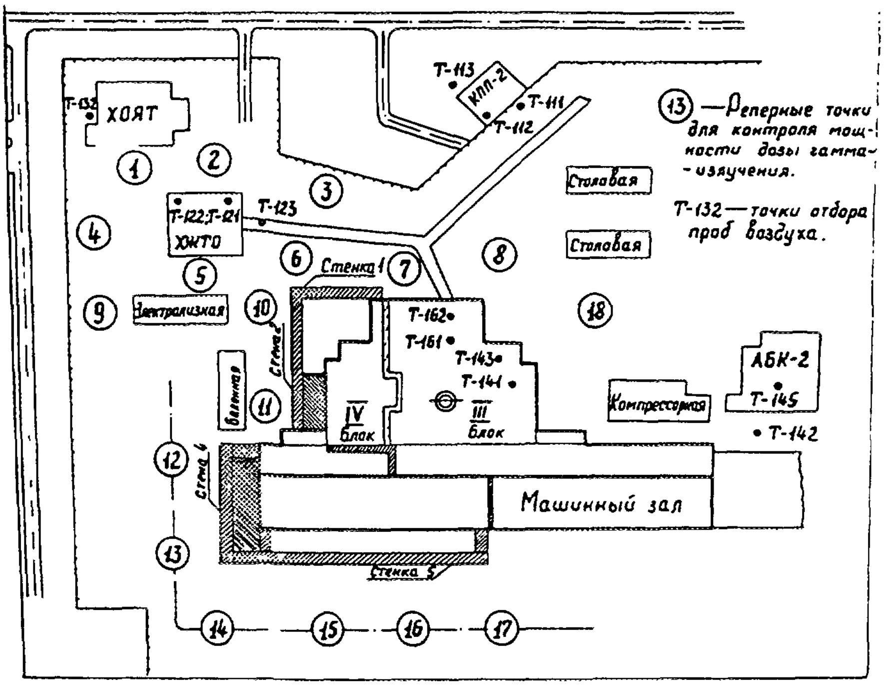

Fig. 7.Fixed sampling point of radiation monitoring on the Chernobyl NPS territory.

1,81+0,48. Such divergence were evidently caused by the energy dependence of the used dosimeters dose sensitivity ("motion with hardness"). Therefore, there were determined spectral characteristics of radiation in different points of the working area. The measurements results showed the real gamma-radiation spectra being considerably "softer" (100 keV) than it should be expected from the scattered fuel radiation (0,55-0,70 MeV).

On the basic of preliminary information there were conventionally determined three characteristic types of radiation fields differing in hardness of gamma-radiation spectrum:

- "hard" fields ($E\gamma$ 0,5 MeV) are typical of working places where radiation of "line of sight" (a floor and a roof of the engine room, rooms with contaminated surfaces, local sources) gives the main contribution into EDR;
- "intermediate" fields" ($E\gamma$ 0,2 MeV) are typical of open sites on the soil with volume distribution of radioactive substances;
- "soft" fields ($E\gamma$ 0,1 MeV) are typical of those working places where sources protected by light materials (crushed rock, soil, concrete) give the main contribution.

Radio nuclide intake was estimated by activity measurement of the petal-type respirators and smears from the nose senuses after the works fulfilment in the atmosphere with the known radio nuclide concentration during some fixed time [14]. To control the body radio nuclide burden, a part of the staff, exposed by external dose of 20 R and higher, was sent into the laboratories of the USSR Ministry of Health to be surveyed with a person radiation counter (PRC), or for radio nuclides determination based on the results of biosubstrata analysis [12].

Building of "Ukrytie" was characterized not only by high levels of radiation, but by large extent of the radioactive source [8]. This caused the necessity to perform RS monitoring not only at the station itself, but in residential area as well, and to take into account exposure doses which were received by the staff their way to the station and to the working places.

The data obtained for radiation monitoring showed that the most dangerous for the personnel was external exposure with gamma-ray quanta. While building "Ukrytie", the radioactive source parameters changed as a result of some technical measures and radio nuclide natural decay (table 1).

The radio nuclide concentration in air was determined both for the total filters activity and for the activity measurement of constituent nuclides separately (spectrometer method).

Air samples for the analysis were taken in predetermined points of the territory and indoors of the ChNPS (fig.7). Furthermore, an armored troop-carrier regularly went round the perimeter and air samples were taken in six points.

Table 1

Time variation dose rates (R/h) on the territory of Chernobyl NPS, R/h

N points on fig.7	1986 10.06	25.07	15.09	25.10	20.11	1987 01.02	29.06
1	2	3	4	5	6	7	8
1	5,6	0,7	0,2	0,07	0,03	0,03	0,015
2	5,6	2,8	0,2	0,07	0,03	0,03	0,02
3	7,0	1,5	0,2	0,07	0,03	0,03	0,018
4	4,8	1,7	0,4	0.20	0,15	0,07	0,03
5	50	2,0	1,2	0,80	0,30	0,26	0,10
6	20	5,0	2,0	0,80	0,30	0,15	0,10
7	30	4,0	2,0	0.80	0,30	0,19	0,06
8	4.0	2,5	1,5	0,10	0,10	0.10	0,03
9	25	10	2,0	1,00	0,30	0,15	0,10
10	40	15	4,0	1.00	0,30	0,21	0,15
11	300	40	5,0	2,00	1,50	0,24	0,40
12	200	55	2,5	1,50	0,80	0,38	0,18
13	400	180	3,0	1,50	0,80	0,50	0,30
14	150	80	3,5	1,50	1,50	0,80	0,25
15	400	70	3,0	1,50	1,50	0,90	0,40
16	180	6,0	3,0	1,50	1,50	1,00	0,20
17	20	3,0	1,7	1,50	1,50	0,60	0,15
18	4.5	4,0	1,5	0,40	0,30	0,10	0,03

Mean air concentration of beta-active nuclides, averaged by the station perimeter from 11 June to 11 July 1986, was 3 10 -11 Ci/l (from 10-12 to 2,5 10-10 Ci/l) (1 Ci = 3,7 1010 Bq). Table 2 gives the levels of atmospheric contamination in the working area.

Analysis of the data on the air conditions in the area of "Ukrytie" building showed that concentration of beta-active aerosols exceeded concentration of alpha-active ones by a factor of 102-103. In particular, in the air samples taken in the rooms of Unit B in July 1986, the average value of beta-activity-alpha-activity relation was 600. In the products released from the reactor this relation was 1100 as on 6 May 1986. But the internal exposure hazard due to alpha-active

Table 2

Air concentration of radionuclides in "Ukrytie" building in 1986

Control point in fig. 7	Average aerosol concentrations, Ci/l					
	Beta-active			Alpha-active		
	July	September	November	July	September	November
1	2	3	4	5	6	7
T-111	-	2,8*10e-12	2,2*10e-12	-	-	-
T-112	-	1,9*10e-12	8,0*10e-13	-	-	-
T-113	2,2*10e-12	2,4*10e-12	8,0*10e-13	4,1*10e-15	2,0*10e-15	2,0*10e-15
T-121	-	6,5*10e-12	1,4*10e-12	-	-	-
T-122	-	3,1*10e-12	2,4*10e-12	-	-	-
T-131	1,6*10e-11	3,9*10e-12	5,0*10e-13	1,9*10e-14	4,0*10e-15	2,0*10e-15
T-132	-	-	7,0*10e-13	-	-	-
T-141	-	1,9*10e-11	1,3*10e-12	6,3*10e-14	4,5*10e-14	3,0*10e-15
T-142	8,0*10e-12	2,9*10e-11	1,6*10e-12	-	-	-
T-143	4,1*10e-11	3,5*10e-11	1,6*10e-12	5,1*10e-14	8,0*10e-15	1,2*10e-15
T-161 (Unit B)	-	1,4*10e-11	1,2*10e-12	-	2,4*10e-14	2,0*10e-15
T-162 (Unit B)	4,5*10e-11	3,8*10e-11	2,1*10e-12	4,5*10e-14	3,1*10e-14	6,0*10e-15
Engine room	8,0*10e-11	-	-	4,4*10e-14	-	-

aerosols is by a factor 2...5 higher in comparison with beta-active ones, in connection with PCA being smaller for alpha-active aerosols (~ by 3 103 fold). Generally, aerosol concentrations in the working area exceeded permissible ones no more than by an order of magnitude. And only during atomizing operations air contamination reached 100...300 PCA. As far as gamma-radiation levels were within the limits of 102...5 104 DMDA (1 DMDA = 2,8 10-3 R/h), the hazard of an internal exposure for the personnel was essentially smaller in comparison with an external exposure.

When personal monitoring in 1986, the ORM employed 12 desks UI-27 and more than 10 thousand of D-2 dosimeters (D-2P), as well as 9 desks UPF-02 with 10 sets of dosimeters DPG-03 with 1250 dosimeters in a set, and 4 ICS desks with 6 thousand of ICS-A dosimeters. There were made about 90 thousand measurements of a cumulative dose and more than 700 thousand measurements of dosimeters D-2. While personal monitoring as a guide there were taken the values of a permissible dose of 25 R for a working period (~ 2 months) and a control level of 1 R for a shift. The monitoring results are given in table 3.

The personal exposure in the time of "Ukrytie" building was nonuniform. Maximum doses were received by the personnel in October-November, while the overlap of the 4 Unit mounting (mean dose 10,4 R). At that time there were cases of higher irradiation (more than 25 R) but in most cases over-exposure didn't exceed 1-3 R.

Selection monitoring of the internal content was carried out for beta-active (gamma-radiating) nuclides by a person radiation counter (PRC). There were inspected 350 officials, who had an external exposure dose of 20 R and more. For 90% of them, radio nuclides body burden was 0,01-0,10 PBA, maximum burden didn't exceed 0,3 PBA (zirconium-95, niobium-95, ruthenium-103, cesium-134,-137). Internal exposure calculated for 50 years doesn't exceed 1 rem (1 rem = 10-2 Sv).

On the basis of the data obtained the conclusion can be drawn that the personnel internal exposure was by a factor of 102 smaller than the external one.

Table 3

Exposure of MC-605 staff in 1986

A number of workers building "Ukrytie"	Mean dose, R	Collective dose, R	A number of workers received an exposure dose within the limits, R					
			0-5	5-10	10-15	15-20	20-25	more than 25
1	2	3	4	5	6	7	8	9
21511	8,57	184451	10890	3039	2474	2627	2320	155
(100%)	-	-	(50,6%)	(14,1%)	(11,5%)	(12,3%)	(10,8%)	(0,7%)

CONCLUSIONS

The ChNPS accident elimination experience led to conclude that large-scale recovery activities are possible in the seat of a accident with disastrous radiological effects, and that it is necessary to improve the force technical equipment and readiness for both emergency and post-emergency activities. Thus, some efforts to improve emergency recovery capabilities in case of nuclear accidents have been now outlined and carried out as part of national programs. These provide for the following:

- to improve computer-aided radiation monitoring systems, radiation survey equipment for remote and wide-range measurements, including on-board devices, and also personal monitoring means;
- to develop certain types of robotics and biologically protected hardware suitable for operations on the site of radiation accident;
- to improve monitoring procedures and software for emergency situations and their elimination;
- to improve decontamination procedures for overalls and personal protection means, as applied in case of major radiation accidents.

Moreover, additional implemented to provide higher readiness of nuclear power and industry facilities for responsive actions in emergency situations and to preclude or eliminate the effects of radiation accidents. The efforts are focused on the following tasks:

- to set up special emergency service centers and formations, qualified and equipped for activities in emergencies, including-accidence at radiological hazardous facilities;
- to establish communication systems and emergency procedures for forces and formations from civil defense and Ministry of Defence engineer and chemical troops;
- to increase readiness capabilities for installation and local forces in case of emergency or critical situations, including emergency readiness exercises at NPS and other high-risk production facilities.

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RADIOLOGICAL CONSEQUENCES OFA HYPOTHETICAL "ROOF BREAKDOWN" ACCIDENT OF THE CHERNOBYL SARCOPHAGUS

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1 Introduction

On behalf of the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety GRS performed investigations with the aim to improve the safety of the Chernobyl Unit 4 shelter in close connection with the Ministry for Environment and Nuclear Safety of the Ukraina from 1992 to1995. One of the tasks of the working programme was concerned with the analysis of hypothetical accidents of the present shelter, which comprises the newly builded Sarcophagus and the remaining ruins of Unit 4. In close collaboration with ukrainian and russian experts the maximum hypothetical accident was defined to be the breakdown of the roof of the Sarcophagus and subsequent release ot the radioactive dust which is mainly located in the destroyed reactor hall and the neighboring rooms.

2 Radioactive dust inside the shelter

The total mass of the radioactive dust, which is mainly located in the destroyed former reactor hall and the neighboring rooms amounts to about 1 t . The dust forms a thin layer of less than 1 mm on the surface of the debris of the destroyed reactor, the walls etc. Although a dust suppression system periodically sprays organic liquid into the reactor hall, an essential part of the dust remains unfixed. Moreover, new dust generation proceeds in the lower rooms due to erosion processes of the lava-like fuel containing material. This dust is partly transported by ventilation into the reactor hall so that the total amount of unfixed dust remains relatively constant over time. The dust distribution was determined by different methods /2/. Regarding the respirable particle fraction in the layer an upper estimation was chosen.

3 Roof construction and accident scenario

The main roof construction consists of two parallel metal griders which are founded in the eastern part on the two remaining ventilation stacks and in the western part on the remaining monolithic western wall. Connection is only due to frictional forçes. Perpendicular to the two me-

Tab. I : Relative mass fraction V of radioactive aerosolparticles inside the shelter depending on aerodynamic equivalent diameter AED [μm] as well as the corresponding deposition velocity v_g [m/s] and washout coefficient Λ_0 [1/s]

V	0.35	0.27	0.08	0.05	0.09	0.16
AED	6.5	17	27	30	32	49
v_g	$1.5 \cdot 10^{-3}$	$9 \cdot 10^{-3}$	$2.1 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$	$3 \cdot 10^{-2}$	$7.2 \cdot 10^{-2}$
Λ_0	$1.5 \cdot 10^{-4}$	$3 \cdot 10^{-4}$	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$	$4 \cdot 10^{-4}$

Tab. II : Composition and activity fractions of the nuclides corresponding to a dust mass of 50 kg (by the end of 1994)

Nuclide	Activity [Bq]
Sr 90	$4.9 \cdot 10^{13}$
Y 90	$4.9 \cdot 10^{13}$
Ru 106	$1.1 \cdot 10^{12}$
Rh 106	$1.1 \cdot 10^{12}$
Cs 134	$2.5 \cdot 10^{12}$
Cs 137	$6.0 \cdot 10^{13}$
Ce 144	$6.5 \cdot 10^{11}$
Pr 144	$6.5 \cdot 10^{11}$
Pm 147	$1.5 \cdot 10^{13}$
Pu 238	$2.7 \cdot 10^{12}$
Pu 239	$2.7 \cdot 10^{11}$
Pu 240	$3.1 \cdot 10^{11}$
Am 241	$4.2 \cdot 10^{11}$

tal griders 27 metal tubes of 1.22 m in diameter and with a length of 34.5 m were put on the metal griders. Above the tubes a roof of shaped steel plates and large-size shields was installed. The total mass of the roof construction was estimated to be 1050 t.

After a strong external impact (e.g. earthquake, wind loads etc.) or internal impact (corrosion, erosion etc.), the breakdown of the western wall and/or the roof cannot be excluded. In the present work a hypothetical breakdown of the roof into the former reactor hall which has roughly the dimensions of 42 m x 42 m (square) x 17 m (height) is assumed. After the breakdown of the roof part of the unfixed radioactive dust becomes airborne. Part of this fraction will settle down again after a short time or will be screened by construction materials or walls. The fraction of airborne radioactive aerosols which will be released due to the turbulent air stream as well as due to the upward stream of about 0.5 m/s, which constantly exists inside the shelter, was roughly estimated to be 5.0 % of the total mass, i.e. 50 kg. This fraction is in accordance with estimates of the Kurchatov Institute, Moscow /2/. The influence of the non radioactive dust was also considered.

4 Diffusion model and input data

The potental radiation exposures for adults on the site and up to 2000 m distance in downwind direction were calculated by means of the GRS computer code BEREG developed on the German Incident Calculation Bases /1/.

The considered exposure pathways are inhalation of aerosol particles with AED < 10 µm during the passing of the radioactive cloud (effective dose D [Sv] by Inhalation = 50 year dose) and ground shine due to gamma-radiation caused by all deposited aerosol particles for a period of 30 days.

5 Diffusion conditions

The diffusion factor was calculated applying the GAUSS model, the diffusion parameters are based on experimental data sets. The influence of the building dimension on plume formation was taken into account as well as the reduction of radioactive material in the plume by radioactive decay, dry deposition and washout.

The ukrainian side defined the atmospheric diffusion category C without rain and a wind speed of 4.2 m/s at 100 m height (corresponding to a wind speed of u = 2.53 m/s at 10 m height). Additionally, calculations were performed for u = 1.0 m/s (at 10 m height) without as well as with rain of intensity 1 mm/h, the dry diffusion categories A and F were also considered.

6 Results

Fig. 1 shows the results for the inhalation doses. The radiation exposure for the diffusion category C decreases only slowly from 50 m to about 200 m. For greater distances a more rapid decrease is obtained. For the wind speed of 2.53 m/s at 10 m height the inhalation doses in the vicinity of 50 m amount to about 1 Sv. At distances above 1100 m does the effective dose decrease below the dose limit of 50 mSv/y for occupationally exposed workers. Assuming a wind speed of 1.0 m/s in correspondence with the German Incident Calculation Bases the doses are increasing by a factor of 2.5 . Hence, the radiological consequences become more severe for lower wind speeds.

A comparison of the results for the categories A, C and F is also shown in Fig. 1. In the vicinity up to 100 m the maximum values are obtained for the categories A and F. The most rapid decrease with distance is observed for category A. Rain has no significant influence on the inhalation dose.

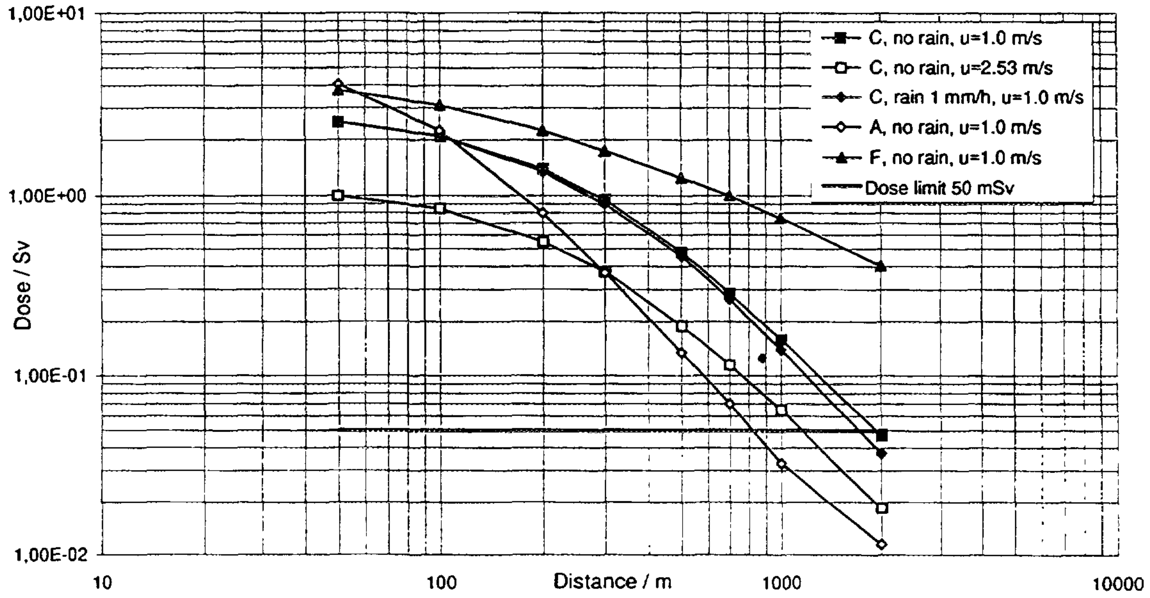

Fig. 1 : Effective Dose by Inhalation

Fig. 2 shows the results for the effective doses due to ground shine for the categories A, C and F. Contrary to inhalation the dose due to ground shine is caused by all aerosol particles, i.e. also in the nonrespirable diameter range. Therefore the dependence of the curves on the distance is slightly changed owing to higher deposition velocities of heavier particles.

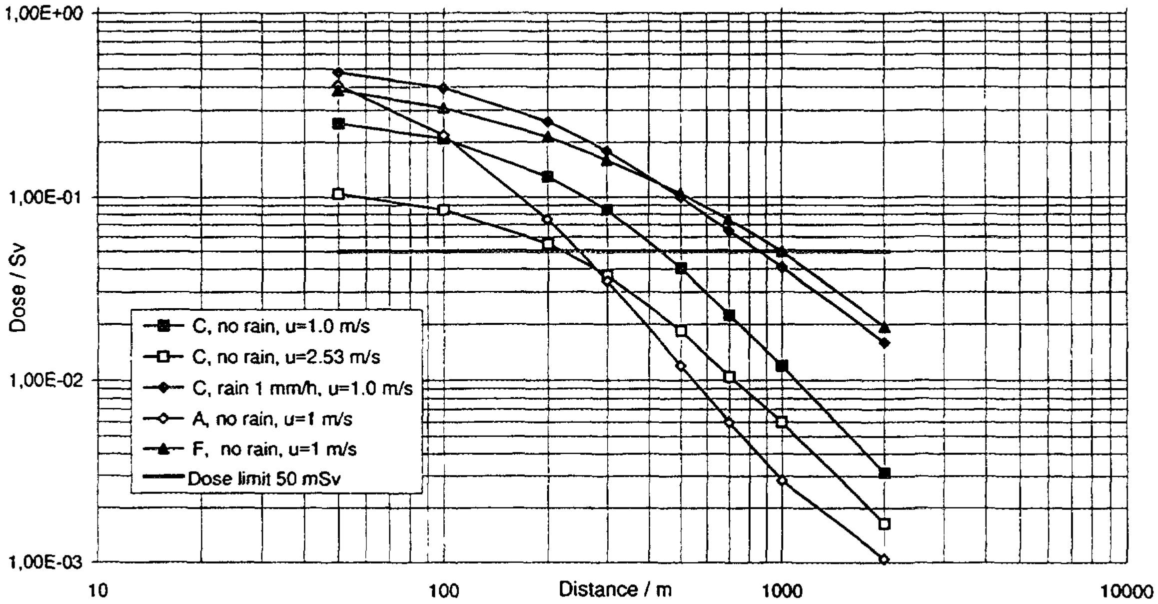

Fig. 2 : Effective Dose by Ground Shine, Exposure 30 Days

In Tables III and IV the contributions of the different nuclides to the inhalation dose and to the ground shine dose are shown.

Tab. III : Fractions of the radiation exposure due to inhalation caused by the different radionuclides

Nuclide	Fraction [%]
Am 241	32.8
Pu 240	24.2
Pu 238	18.5
Pu 239	17.4
Sr 90	6.7

Tab. IV : Fractions of the radiation exposure due to ground shine caused by the different radionuclides

Nuclide	Fraction [%]
Cs 137	89.6
Cs 134	9.7
Ru 106	0.5
Ce 144	0.1

The ground shine dose is approximately linear in time so that shorter exposure periods can easily be scaled down. Only for longer exposure periods of some years the contribution of Cs 137 is more dominant than in Tab. IV.

7 Conclusions

The doses due to inhalation in the vicinity of the shelter up to 200 m are very high predominantly for low wind speeds and exceed the dose limit of occupationally exposed workers.

Except for the stable diffusion category F for all other weather conditions, the inhalation dose decreases below the limit for distances above 2000 m, so that a relevant hazard for longer distances, e.g. for the town of Chernobyl, is not to be expected. The inhalation dose is predominantly caused by long lived transuranium nuclides, hence the choice of the moment of the accident (e.g. end of 1994) does not play any important role.

Compared to the inhalation the effective doses due to ground shine for an exposure period of 30 days are generally lower by about one order of magnitude and show a similar behaviour depending on the distance.

The ground shine dose is primarily caused by long lived nuclides of fission products, e.g. Cs 137, so that again the choice of the moment of the accident does no matter.

Contrary to the inhalation the doses due to ground shine are signifcantly influenced by the duration of exposure and also by the intensity of rain during the accident. Depending on the given weather conditions, it is possible for a person to stay for several days on the NPP site after the accident and not exceed the dose limit.

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SESSION 8

RADIATION INCIDENTS INVOLVING HUMAN EXPOSURE IN THE FORMER USSR BEFORE AND AFTER CHERNOBYL

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XA9745905

Международная конференция
"Десятилетие после Чернобыля: оценка последствий аварии"

РАДИАЦИОННЫЕ ИНЦИДЕНТЫ, СВЯЗАННЫЕ С ОБЛУЧЕНИЕМ ЧЕЛОВЕКА, НА ТЕРРИТОРИИ БЫВШЕГО СССР ДО И ПОСЛЕ ЧЕРНОБЫЛЯ

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Chernobyl accident has changed the people representations on the degree of danger for the person of development of a nuclear power. From more than 384 people involved, from 134 suffered from acute radiation syndrome, from which 28 persons were died at the acute period. And what has been happening *before* and *after* Chernobyl? Which radiating incidents took place on a territory of former USSR and on which "background" Chernobyl consequences are observed?

Materials of the Registry of SRSR - Institute of Biophysics (IBP), which clinical department has provided medical assistanse, observation and treatment in the majority of victims damaged at radiating incidents on a territory of former USSR, certifies that at least 147 radiating incidents have taken place for a period from 1950 to 1996 (excluding South Urals accidents, nuclear submarine accidents and consequences of nuclear explosions). More than 776 individuals were exposured in these incidents.

It is authentically known, that at least 393 of them were observed with clinical symtoms of acute radiation injury, local radiation damages or their combinations, and 57 patients were died during acute period of radiation injury and about half of given statistics has on Chernobyl acident. More than half of cases (79 of 147) was connected to a radioisotope devices and their sources of radiations.

In the last three decades small fluctuations of frequency of radiating incidents, on the average are observed: about 3-4 cases in a year (maximum9, 1971), from which, only 1-2 with two and more damaged and about one case in two years with fatal outcomes at the acute period. Quantity of victims with clinical symtoms makes on the average 5-6 in a year, and with fatal outcome - on the average less than one case in a years before Chernobyl accident and only three cases for 10-year period after Chernobyl.

Чернобыльская авария изменила в умах людей представление о степени опасности для человека развития ядерной энергетики. 28 погибших в результате непосредственного участия в аварийных работах и 134 перенесших острую лучевую болезнь - вот плата за пренебрежение к соблюдению техники безопасности при работе со сложными ядерно-техническими установками. А что же было *до* и *после* Чернобыля? Какова структура непосредственных медицинских последствий других радиационных инцидентов и на каком "*фоне*" наблюдаются последствия Чернобыля? Ответы на эти и некоторые другие вопросы попытались получить авторы данной работы на основании анализа всех известных случаев, связанных с облучением людей, имевших место на территории бывшего СССР.

Под структурой непосредственных медицинских последствий подразумевается информация об общем числе вовлеченных в радиационный инцидент, а также о числе пострадавших с клинически наблюдаемой симптоматикой (острая лучевая болезнь и местные лучевые поражения, а также их комбинация), включая данные об умерших в острый период.

В данном сообщении приводятся материалы регистра ГНЦ РФ - Института биофизики (ИБФ), в клиническом отделе которого (на базе больницы №6, г. Москва) и филиале №1 ИБФ (г. Озерск) в течение четырех с половиной десятилетий проходили медицинское обследование и лечение большинство пострадавших при тяжелых радиационных инцидентах и нуждавшихся в специализированной медицинской помощи. В прошлом информация такого рода, особенно об условиях и месте облучения, являлась, зачастую, строго секретной и, как следствие этого, публикации по многим из анализируемых случаев отсутствуют. Полных подобных сведений по стране до настоящего времени не имеется. Это связано, прежде всего, с сохраняющейся и доныне тенденцией ограничения доступа к ведомственным архивам.

В настоящее время данные о полученных дозах, результаты клинических и лабораторных анализов, сведения о симптомах реакции, исходах острой лучевой болезни и осложнениях по каждому пациенту, проходившему обследование и/или лечение, а также немногие литературные данные, в основном, внесены в компьютерную базу данных (регистр ИБФ). Последний является необходимым элементом поиска общих закономерностей реакции человека на облучение, в т.ч. в условиях неоднородного в пространстве и времени поля излучения, испытания диагностических методик и математических моделей, оценки эффективности тех или иных методов обработки пострадавших и курсов лечения, а также основой для создания прикладных компьютерных систем поддержки принятия решения при диагностике и лечении острых лучевых поражений.

Авторы отчетливо представляют, что регистр ИБФ не претендует на абсолютную полноту данных, вследствие того, что он, в основном, предназначался для регистрации пострадавших в радиационных авариях с клинической симптоматикой. Так, в регистре явно занижена численность группы вовлеченных в аварийные ситуации лиц без клинических проявлений лучевой болезни. Однако, постоянно проводимая работа по их дополнительному выявлению в рамках 1-го межведомственного экспертного совета, позволяет дополнить и уточнить информацию, содержащуюся в регистре и убедиться, что случаи с явными клиническими поражениями не были пропущены. Таким образом, можно утверждать, что ни один регистр не содержит более подробной и полной информации о непосредственных медицинских последствиях в результате радиационных инцидентов на территории бывшего СССР.

В табл. 1 приведен перечень радиационных инцидентов, внесенных в регистр ИБФ (за исключением двух известных радиационных аварий на Южном Урале в результате деятельности ПО "Маяк" 1957 и 1967 г.г., аварий на атомных подводных лодках и последствий ядерных взрывов), сведения о месте, где они произошли, основных характеристиках радиационного воздействия, а также о числе вовлеченных людей, в том числе с клинически значимыми симптомами и погибших в острый период лучевой болезни.

Остаются и на сегодняшний день некоторые вопросы, в частности, точная дата или место некоторых инцидентов, а также в ряде случаев, точное число вовлеченных в ситуации и/или пострадавших лиц. В отдельных случаях удается уточнить некоторые сведения об инциденте, но, к сожалению, часть информации безвозвратно утеряна. Несмотря на это, мы считаем, что приближения, связанные с неточностью наших знаний не влияют существенно на количественные оценки и выводы, сделанные в рамках настоящего сообщения.

Анализ табл. 1 показывает, что начиная с середины 50-х годов география радиационных инцидентов расширилась и вышла за пределы Уральского региона (г. Челябинск). Это напрямую связано с тем, что наряду с производством ядерного оружия, энергия атома находила все большее применение в народном хозяйстве. Первые аварии, в результате которых облучались люди, в основном, были связаны с потерей контроля над критичностью делящегося материала, в

Таблица 1. *Радиационные инциденты, имевшие место на территории бывшего СССР и структура их непосредственных медицинских последствий (регистр ИБФ, состояние на 12.02.96)*

Дата инци-дента	Локализация		Основные радиационные характеристики			Число вовлеченных					
	Текущее наиме-нование страны	Город или район (комментарии)	Тип инци-дента *)	Основной радиаци-онный фактор	Харак-тер облу-чения	Все-го	с клиническими симптомами				
							Все-го	ОЛБ		То-лько МЛП	Уме-рших
								Все-го	ОЛБ +МЛП		
1	2	3	4	5	6	7	8	9	10	11	12
19.08.50	Россия	Челябинск	крит	γ–n	внеш.	3	3	3	3?	-	-
??.??.51	Россия	Челябинск-40	р(ТВ)	γ–β	внеш.	1	1	1	1	-	-
01.10.51	Россия	Челябинск-40		γ–β	внеш.	7	4	4	-	-	1
02.12.51	Россия	Челябинск	р(ТВ)	γ–n	внеш.	2	2	2	-	-	-
??.??.52	Россия	Челябинск		β(НТО)	внутр.	2	2	2	-	-	2
04.07.52	Россия	Челябинск-40	крит	γ–n	внеш.	1	1	1	-	-	-
??.??.53	Россия	Челябинск		β(НТО)	внутр.	2	2	2	-	-	-
15.03.53	Россия	Челябинск-40	крит	γ–n	внеш.	2	2	2	-	-	-
09.09.53	Россия	Москва	крит	γ–n	внеш.	7	4	4	4	-	-
18.09.53	Россия	Челябинск	?	γ–n	внеш.	2	1	1	-	-	-
13.10.53	Россия	Челябинск-40	р(ТВ)	γ–n	внеш.	5	5	5	-	-	-
28.12.53	Россия	Челябинск-40	р(ТВ)	γ–n	внеш.	9	7	7	-	-	-
11.03.54	Россия	Обнинск	крит	γ–n	внеш.	10	1	1	1	-	-
28.06.54	Россия	Арзамас-16 (МСЧ-50)	ист.	β(^{210}Po)	внеш.	2	2	2	1	-	1
24.01.55	Россия	Москва (ЛИПАН)	ист.	γ(^{124}Sb)	внеш.	1	1	1	1	-	-
03.06.55	Россия	Челябинск	крит ?	γ–n	внеш.	2	2	2	-	-	-
22.04.57	Россия	Челябинск-40	крит	γ–n	внеш.	9	9	9	9?	-	1
02.01.58	Россия	Челябинск-40	крит	γ–n	внеш.	4	4	4	4?	-	3
08.06.60	Россия	Москва	суиц.	γ	внеш.	1	1	1	1	-	1
20.03.61	Россия	Москва (ИФХ)	у	γ(^{60}Co)	внеш.	1	1	1	1	-	-
26.06.61	Россия	Москва	крит	γ–n	внеш.	4	4	4	-	-	-
14.07.61	Россия	Томск	крит	γ–n	внеш.	1	1	1	-	-	-
02.11.62	Россия	Обнинск	крит	γ–n	внеш.	2	2	2	2	-	-
??.??.63	Россия	Челябинск		β(НТО)	внутр.	1	1	1	-	-	-
11.03.63	Россия	Арзамас	крит	γ–n	внеш.	6	2	2	1	-	-
14.05.64	Россия	Москва (ИАЕ)	крит	γ–n	внеш.	3	-	-	-	-	-
26.09.64	Россия	Северодвинск (МСЧ-58)	у(дф)	γ–β (^{170}Tu)	внеш.	4	1	1	-	-	-
07.02.65	Россия	Северодвинск (МСЧ-58)	р	γ–n	внеш.	1	-	-	-	-	-
12.02.65	Россия	Северодвинск (МСЧ-58)	р	γ–n	внеш.	1	-	-	-	-	-
22.12.67	Россия	Москва (ИБФ)	ист.	γ–β(^{46}Sc)	внеш.	1	1	1	1	-	-
05.04.68	Россия	Челябинск (Сунгуль)	крит	γ–n	внеш.	2	2	2	2	-	2
27.06.68	Россия	Арзамас	у	β(^{210}Po)	внутр.	3	2	-	-	2	-
23.10.68	Украина	Киев (ИФАН)	р	γ–β	внеш.	1	1	1	-	-	-
10.12.68	Россия	Челябинск	крит	γ–n(Pu)	внеш.	2	2	2	2	-	1
??.??.69	?	?	у(ст)	γ	внеш.	1	1	1?	-	-	-
20.01.69	Россия	Обнинск	р	γ	внеш.	2	2	2	-	-	-
11.02.69	Россия	Москва (ВНИИХТ)	ускор.	e	пучок	1	1	1	1	-	-
11.03.69	Россия	Мелекес (МСЧ-65)	у	γ(^{60}Co)	внеш.	1	1	-	-	1	-
22.04.69	Россия	(МСО-99)	р	γ–β	внеш.	4	2	1	1	1	-
07.05.69	Россия	Воронеж (АЭС)	р(ТВ)	γ	внеш.	2	2	2	-	-	-
24.09.69	Россия	Томск-7 (МСЧ-81)		γ–β	внеш.	2	2?	2?	1?	-	-
13.10.69	Россия	(МСЧ-2)	у(дф)	γ(^{192}Ir)	внеш.	1	1	-?	-?	1?	-
04.02.70	Украина	Киев (ИФАН)	крит	γ–n	внеш.	2	1	1	1	-	-
13.02.70	?	?	у	γ(^{60}Co)	внеш.	1	1	1	1	-	-
15.04.70	Россия	Москва	ускор.	e	пучок	1	1	-	-	1	-

18 01 71	Россия	Сормово	р	γ-β	внеш	7	5	5	5	-	3
15 02 71	Россия	Москва (ИАЭ)	крит	γ-n	внеш	4	3	3	2	-	-
26 05 71	Россия	Москва (ИАЭ)	крит	γ-n	внеш	7	4	4	3	-	2
10 07 71	Россия	Редкино (МСЧ-57)	у	X	пучок	1	-	-	-	-	-
26 07 71	Россия	Голицино	у	$\gamma(^{60}Co)$	внеш	1	1?	1?	-	-	-
?? 09 71	Россия	Воронеж (АЭС)	р	γ-β	внеш	1	1	-	-	1	-
02 12 71	Россия	Мелекес (МСЧ-65)	ист	$\gamma(^{137}Cs)$	внеш	1	-	-	-	-	-
02 12 71	Россия	(МСЧ-61)	у	X	пучок	1	1?	-	-	1?	-
17 12 71	Россия	(МЧС-61)	у	X	пучок	1	1?	-	-	1?	-
11 02 72	Россия	Комсомольск-на-Амуре	у(дф)	$\gamma(^{137}Cs)$	внеш	8	8?	8?	-	-	-
27 03 72	Украина	Львов (Университет)	у	X	пучок	1	-	-	-	-	-
07 06 72	Россия	Горький	ист	$\gamma(^{137}Cs)$	внеш	3	3?	3?	1?	-	-
09 10 72	Россия	Приморский Край(МСЧ-98)	ист	$\gamma(^{192}Ir)$	внеш	1	1	1?	1?	-	-
17 03 73	Украина	Одесса	ист	$\gamma(^{60}Co)$	внеш	1	1	1	1?	-	-
20 06 73	Россия	Москва (СНИП)	ист	$\gamma(^{60}Co)$	внеш	1	1	-	-	1?	-
26 07 73	Россия	Электрогорск	у	$\gamma(^{60}Co)$	внеш	2	1	1?	-	-	-
09 01 74	Россия	Новосибирск	у	X	пучок	1	1	-	-	1	-
20 05 74	Россия	Воронеж (АЭС)	р(ТВ)	γ-β	внеш	2	2?	-	-	2?	-
24 05 74	Россия	Томск-7 (МСЧ-81)	ист	$\beta(^{106}Rh)$	внеш	1	1	-	-	1	-
15 12 74	Россия	Липецк	ист	$\gamma(^{137}Cs)$	внеш	2	2	1	1	-	-
12 04 75	Россия	Москва (Нефтехим ин-т)	у	$\beta(^{90}Sr+^{90}Y)$	внеш	1	1?	-	-	1?	-
20 06 75	Россия	Казань	у	$\gamma(^{60}Co)$	внеш	2	2	2	2	-	-
11 07 75	Россия	Свердловск	ист	$\gamma(^{60}Co)$	внеш	3	3	3	1	-	1
15 11 75	?	?	ист	$\gamma(^{137}Cs)$	внеш	5	1?	1?	1?	-	-
12 07 76	Россия	Москва (ВНИИФТРИ)	у	$\gamma(^{60}Co)$	внеш	1	1	1	-	-	-
22 07 76	Россия	Мелекес (МСЧ-65)	у	γ-β	внеш	1	1	-	-	1	-
05 03 77	Россия	Обнинск	крит	γ-n	внеш	1	1	1	1	-	-
05 03 77	Украина	Киев	ускор	p+	пучок	1	1	1	1	-	-
16 11 77	Россия	Красноярск (МСЧ-51)	суиц	$\gamma(^{137}Cs)$	внутр	1	-	-	-	-	-
07 03 78	Россия	Приморский Край(МСЧ-98)	у(дф)	$\gamma(^{192}Ir)$	внеш	1	1?	-	-	1?	-
04 04 78	Россия	Приморский Край(МСЧ-98)	у(дф)	$\gamma(^{192}Ir)$	внеш	1	1?	-	-	1?	-
03 06 78	Россия	Протвино	ускор	p+	пучок	1	1	1	-	-	-
21 09 78	Россия	Москва (ИАЭ)	ускор	e	пучок	1	1?	-	-	1?	-
17 10 78	Россия	Москва (ИАЭ)	р	β	внеш	1	1	-	-	1	-
25 11 78	Россия	Удмуртия	у(дф)	$\gamma(^{192}Ir)$	внеш	1	1?	-	-	1?	-
13 12 78	Россия	Томск	крит	γ-n	внеш	7	3	3	1	-	-
08 05 79	Россия	Свердловск	р(ТВ)	γ-β	внеш	1	1	-	-	1	-
20 07 79	Россия	Ленинград (ЦНИРРИ)	ускор	e	пучок	2	2	2	2	-	-
20 09 79	Киргиз	Фрунзе	у(дф)	$\gamma(^{192}Ir)$	внеш	1	1	1	1	-	-
01 12 79	Казахс	Семипалатинск	у	$\gamma(^{60}Co)$	внеш	1	1	1	1	-	-
31 01 80	Россия	Москва (ИФХ)	у	$\gamma(^{60}Co)$	внеш	1	-	-	-	-	-
23 05 80	Россия	Челябинск	у	X	пучок	1	1	-	-	1	-
01 09 80	Россия	Ленинград	у(ст)	$\gamma(^{60}Co)$	внеш	1	1	1	1	-	1
19 09 80	Россия	Южно-Сахалинск	ист	$\gamma(^{192}Ir)$	внеш	2	1	1	1	-	1
03 12 80	Россия	Владивосток	у(дф)	$\gamma(^{192}Ir)$	внеш	1	1	-	-	1	-
30 12 81	Россия	Северодвинск (МСЧ-58)	у(дф)	$\gamma(^{192}Ir)$	внеш	1	1?	1?	1?	-	-
19 05 82	Россия	Смоленск (АЭС)	у(дф)	$\gamma(^{192}Ir)$	внеш	4	1	-	-	1	-
14 06 82	Туркм	Ашхабад (НИИО)	у	$\gamma(^{60}Co)$	внеш	13	7	5	5	2	-
09 01 82	Россия	Краматорск	ист	$\gamma(^{137}Cs)$	внеш	5	4?	4?	2?	-	1
05 10 82	Азерб	Баку (в/ч)	ист	$\gamma(^{137}Cs)$	внеш	22	21	14	14?	7?	5
18 12 82	Россия	Уренгой	у(дф)	$\gamma(^{192}Ir)$	внеш	2	2?	-	-	2?	-
27 01 83	Россия	Москва (ИФХ)	у	X	пучок	1	1	1	1	-	-
28 04 83	Украина	Харьков	у(дф)	$\gamma(^{137}Cs)$	внеш	2	2	1	1	1	-

17.05.83	Россия	?	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
11.06.83	Россия	Уфа	у(дф)	$\gamma(^{137}Cs)$	внеш.	1	1	-	-	1	-
12.08.83	Россия	Смоленск (АЭС)	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	-	-	-	-	-
11.10.83	Узбек.	Навои	ист.	$\gamma(^{75}Se)$	внеш.	2	2?	2?	2?	-	-
07.12.83	Россия	Уфа	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
27.01.84	Россия	Курск (АЭС)	р	$\gamma-\beta$	внеш.	2	2?	1?	1?	1?	-
07.02.84	Россия	Пермь	у(дф)	$\gamma(^{192}Ir)$	внеш.	7	7?	6?	4?	1?	-
25.02.84	Украина	Южно-Украинская АЭС	у(дф)	$\gamma(^{192}Ir)$	внеш.	6	-	-	-	-	-
12.06.84	Россия	Уфа	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
15.06.84	Россия	Горький	ист.	$\gamma(^{192}Ir)$	внеш.	11	7	7	7	-	-
24.10.84	Россия	(МСЧ-13)	у(дф)	$\gamma(^{124}Sb)$	внеш.	1	1?	-	-	1	-
03.03.85	Россия	Норильск	ист.	$\gamma(^{137}Cs)$	внеш.	3	3	3	3	-	-
26.09.85	Россия	Игналинская АЭС	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	1	1	-	-
04.11.85	Россия	Москва (ИАЭ)	у(дф)	$\gamma(^{60}Co)$	внеш.	1	1?	1?	-	-	-
26.04.86	Украина	Чернобыль (АЭС)	р	$\gamma-\beta$	внеш.	384[x]	134	134	54	-	28
11.06.86	Россия	Обнинск	у	$\gamma(^{60}Co)$	внеш.	1	1	1	1	-	-
05.08.86	Россия	Калинин (АЭС)	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
01.02.87	Россия	Москва (ИАЭ)	у	X	пучок	1	1	-	-	1	-
08.06.87	Армен.	Армянская АЭС	р	$\gamma-\beta$	внеш.	2	-	-	-	-	-
08.09.87	Россия	Москва (ИАЭ)	ист.	$\gamma(^{137}Cs)$	внутр.	1	-	-	-	-	-
22.03.88	Россия	Свердловск	ист.	$\beta(^{90}Sr+^{90}Y)$	внеш.	3	3	3	3	-	-
04.05.88	Узбек.	Ташкент	у(дф)	$\gamma(^{192}Ir)$	внеш.	3	2	2	2	-	-
20.03.89	Россия	Москва (ЦНИИ АТОММАШ)	у	X	пучок	1	1	1	1	-	-
08.04.89	Россия	(МИНГАЗСТРОЙ)	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	1	1	-	-
14.08.89	Россия	Загорск	ускор.	e	пучок	1	1	1	1	-	-
30.10.89	Россия	Москва (МГУ)	у	X	пучок	1	1	1	1	-	-
27.02.90	Россия	Калинин (АЭС)	ист.	$\gamma(^{192}Ir)$	внеш.	1	1	1	1	-	-
??.03.90	Украина	Краматорск	ист.	$\gamma(^{137}Cs)$	внеш.	4+1?	1+1?	-	-	1+1?	-
13.03.90	Россия	Москва (НИИТ)	ускор.	e	пучок	1	1	1	1	-	-
28.05.90	Россия	Комсомольск-на-Амуре	у(дф)	$\gamma(^{60}Co)$	внеш.	1	-	-	-	-	-
13.09.90	Украина	Харьков	ист.	$\gamma(^{192}Ir)$	внеш.	1	1	1	1	-	-
01.11.90	Россия	Комсомольск-на-Амуре	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	1	1	-	-
14.05.91	Россия	Игналинская АЭС	р(ТВ)	$\gamma-\beta$	внеш.	3	-	-	-	-	-
24.08.91	Россия	Братск	у	$\gamma(^{137}Cs)$	внеш.	3	2	2	1	-	-
26.10.91	Белар.	Несвиж	у(ст)	$\gamma(^{60}Co)$	внеш.	1	1	1	1	-	1
09.01.92	Россия	Рязань	у(дф)	$\gamma(^{192}Ir)$	внеш.	2	2	2	2	-	-
25.05.92	Казахс.	Аксай	у(дф)	$\gamma(^{192}Ir)$	внеш.	4	1	1	1	-	-
14.04.93	Россия	Москва	крим	$\gamma(^{137}Cs)$	внеш.	23	1	1	1	-	1
07.08.93	Россия	Димитровград	р	$\gamma-n$	внеш.	3?	1	-	-	1	-
11.07.93	Эстония	Таллинн	ист.	$\gamma(^{137}Cs)$	внеш.	9	4	2	1	2	1
12.07.93	Россия	Вологда	ист.	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
09.11.93	Россия	Тульская обл.	ист.	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
07.09.94	Россия	Москва		$\alpha(^{239}Pu)$	внутр.	11	-	-	-	-	-
28.11.94	Россия	Воронеж	у	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
18.03.95	Россия	Первоуральск	у	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
07.07.95	Россия	Москва	крим?	$\gamma(^{137}Cs)$	внеш.	1	1	-	-	1	-
11.09.95	Россия	Москва	ист	$\gamma(^{137}Cs)$	внутр.	1	1	-	-	1	-
03.10.95	Россия	Нижний Новгород	у(дф)	$\gamma(^{192}Ir)$	внеш.	1	1	-	-	1	-
08.02.96	Россия	Москва	ист	$\gamma(^{11}C)$	внеш.	1	1	-	-	1	-

*) В табл. (колонка 4) приняты следующие сокращения: *р* - инциденты, связанные с атомными реакторами, в т.ч. *р(ТВ)* - операции сТВЭЛами; *крит* - потеря контроля над критичностью делящегося материала *у* - рентгеновская или радиоизотопная установка, в частности: *у(ст)* - стерилизационная или *у(дф)* - гамма-деффектоскоп, *ист.* - инциденты с радиоизотопными источниками от промышленных или исследовательских установок; *крим* - криминальные случаи; *суиц* - случаи суицида

[x] не включая "ликвидаторов"

последующие же десятилетия такие инциденты практически не имели место. 20 инцидентов (14% от всех случаев на территории бывшего СССР из регистра ИБФ) произошел за пределами территории Российской Федерации. За рассматриваемый период имеют место тенденции снижения доли профессионалов среди пострадавших, а также увеличения численности лиц, вовлеченных в ситуацию без клинических проявлений лучевой болезни.

На рис. 1 представлена динамика изменения частоты радиационных инцидентов по годам за рассматриваемый период. За последние три десятилетия наблюдаются небольшие колебания частоты радиационных инцидентов, в среднем, около 3-4 в год (максимум - 9, 1971 г.), из которых, в среднем, лишь 1-2 с двумя и более пострадавшими и не более двух случаев в год (в среднем - один случай в два-три года) со смертельными исходами в острый период.

На рис. 2 дана динамика изменения среднегодового числа вовлеченных в радиационные инциденты. Количество пострадавших с клинически значимыми симптомами составляет в среднем 5-6 в год, не учитывая Чернобыльской аварии, а со смертельным исходом - в среднем менее одного случая в год до Чернобыльской аварии и всего три случая за 10-летний период (в среднем один случай за три года) после.

В табл. 2 представлены обобщенные данные по определенным условным типам радиационных инцидентов и структуре их непосредственных медицинских последствий.

Как видно из табл. 1, 2 за период с **1950 по 1996 г.г.** на территории бывшего СССР произошло по крайней мере **147** радиационных инциндента, информация о которых документирована в регистре ИБФ (данные на 12.02.96 г.). Облучению подверглись **не менее 776 человек**. По крайней мере у **393** из них наблюдались **клинические симптомы** острой лучевой болезни, местных лучевых поражений или их сочетаний, а **57 - погибли** в острый период развившейся лучевой болезни.

Более половины проанализированных случаев (79 из 147) связаны с радиоизотопными установками и их источниками излучений, причем из них лишь четверть (20 из 79) связана с двумя и более пострадавшими с клинической симптоматикой и чуть более 10% (9 из 79) - со смертельными исходами. При этом, наиболее тяжелые последствия связаны с источниками ^{137}Cs (18 случаев из 79, четыре инцидента привели к гибели 8 человек).

В шесть радиационных инцидентов (кроме Чернобыльского) на атомных станциях до настоящего времени было вовлечено всего 12 человек, у 8 из которых наблюдались клинические симптомы и ни один человек не погиб.

Обращают на себя внимание некоторые закономерности ситуаций с γ-β источниками. В основном, они отличаются наибольшей численностью вовлеченных в аварию, в т.ч. лиц из населения, и требуют сложных организационных мероприятий по выявлению реально облученных и пострадавших от облучения. Это типично также и для других стран (Мексика, 1983; Бразилия, 1987).

8 инцидентов имело место на ускорителях (6 - на ускорителях электронов и 2 - протонов, в основном, кроме одного случая, с одним пострадавшим), в результате которых 9 человек были облучены и у них наблюдались клинически значимые симптомы (ни одного смертельного случая). Зарегистрированные эпизоды с рентгеновскими установками (10 случаев) привели к последствиям с клинической симптоматикой у восьми из десяти пострадавших, ни одного смертельного случая.

В общей структуре непосредственных медицинских последствий радиационных инцидентов (зарегистрированных в регистре ИБФ, за исключением указанных выше двух южноуральских аварий, аварий на атомных подводных лодках и последствий ядерных взрывов), Чернобыльская авария составляет примерно половину по каждой из рассмотренных позиций от общего количества персонифицированных случаев облучения (384 из 776 общего числа вовлеченных (50%), в т.ч. 134 из 259 (52%) с клиническими симптомами и 28 из 57 (49%) погибших). Более четверти всех случаев с клинической симптоматикой обусловлены местными

Таблица 2 Основные типы радиационных инцидентов на территории бывшего СССР и структура их непосредственных медицинских последствий (по материалам регистра ИБФ, состояние на 12 02 96)

Классификация инцидентов	Основные радиационные факторы	Количество радиационных инцидентов: общее	в т ч с двумя и более пострадавшими	в т ч со смертельными исходами	Число вовлеченных: всего	в т ч с клиническими симптомами: всего	ОЛБ: всего	ОЛБ + МЛП	МЛП только	в т ч умерших
Инциденты с радиоизотопными установками и их источниками излучений (всего)		79	20	9	214	141	98	74	43	13
в т ч ^{60}Co	γ	18	3	3	34	25	21	15	4	3
^{137}Cs	γ	18	8	4	96	55	40	26	15	8
^{192}Ir	γ	32	5	1	64	45	27	25	18	1
другие γ-излучатели	γ	4	1	-	5	5	3	3	2	-
(γ–β)-излучатели	γ–β	2	-	-	5	2	2	1	-	-
β-излучатели	β	5	3	1	10	9	5	4	4	1
Реакторные инциденты и потеря контроля над критичностью делящегося материала (всего)		39 (+1*)	23 (+1*)	6 (+1*)	129 +384ˣ	86 +134*	78	44	8	12 (+28*)
в т ч потеря контроля над критичностью	γ–n	20	14	5	79	51	51	36	-	9
Чернобыльская авария	γ–β	1*	1*	1*	384ˣ	134*	134*	54*	-	28*
реакторные инциденты (другие причины)	γ–β	19	10	1	50	35	27	8	8	3
Рентгеновские установки и ускорители (всего)		18	1	-	19	17	10	9	7	-
в т ч рентген установки	X	10	-	-	10	8	3	3	5	-
ускорители электронов	e	6	1	-	7	7	5	5	2	-
ускорители протонов	p+	2		-	2	2	2	1	-	-
Другие инциденты (всего)		10	4	3	30	15	14	2	1	4
ИТОГО		146 (+1*)	48 (+1*)	18 (+1*)	392 +384ˣ	259 +134*	200 + 134*	129 (+54*)	59 (0*)	29 (+28*)

*) в результате аварии на ЧАЭС

ˣ не включая "ликвидаторов"

лучевыми поражениями без развития острой лучевой болезни. Необходимо только отметить, что к числу вовлеченных в Чернобыльскую аварию отнесено в настоящем обзоре только 384 человека, которые подверглись радиационному воздействию в первые дни после аварии и обрабатывались и/или наблюдались в клиниках Москвы и Киева. Большая когорта "ликвидаторов", которые подвергались радиационному воздействию в условиях контроля ситуации, не анализиуется

Итак, в заключении можно смело утверждать, что если бы не Чернобыльская авария, то непосредственная опасность для жизни человека от развития атомной энергетики и широкого использования радиоизотопов, рентгеновских установок и ускорителей заряженных частиц в промышленности, медицине и науке в нашей стране, значительно меньше, чем от развития других отраслей народного хозяйства

В то же время уроки Чернобыля показывают, насколько важно соблюдение технологической дисциплины именно в атомной энергетике, т.к прямой и косвенный экономический и моральный ущерб от одной лишь Чернобыльской аварии, оказался настолько большим, что лишь ликвидация ее последствий в загрязненных районах и в сознании людей является задачей не только нашего, но и грядущих поколений.

XA9745906

COMPARISON OF THE EXPOSURE DOSES RECEIVED BY THE PUBLIC IN THE RUSSIAN FEDERATION FOLLOWING THE ATMOSPHERIC NUCLEAR TESTS CONDUCTED AT THE TESTING GROUNDS OF THE FORMER USSR, AND AFTER THE CHERNOBYL ACCIDENT

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“Десятилетие после Чернобыля: оценка последствий аварии”

Сопоставление доз облучения населения Российской Федерации после проведения ядерных испытаний в атмосфере на полигонах бывшего СССР и после аварии на Чернобыльской АЭС

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Studies of the consequences of radiation emergencies, which occurred on the territory of the Russian Federation for a variety of reasons, are of great scientific as well as social and political importance.

Sound data on public exposures in the area affected by the Semipalatinsk atmospheric nuclear tests are presented in the reports on the “ Semipalatinsk Test Site - Altai “ programme and in an IAEA publication (Assessing the radiological impact of past nuclear activities and events, July 1994). Summing up the archival information and radiation survey evidence resulted in an album showing essentially all contaminated off-site spots with doses of above 0.1-0.5 cSv.

A good deal of effort has also been undertaken in collecting and pooling the experimental data on environmental radioactive contamination and the radiation survey results for the area affected by the Novozemelsky tests. This material served as the basis for estimation of potential public exposures in 21 regions of Russia.

The Table gives population size values for the areas contaminated due to atmospheric nuclear testing at the both test sites of the former USSR and potential maximum, average and collective external doses to the population in 30 Russian regions. For all the regions, average individual doses to the population are shown to be below 1 cSv, in the range of 0.12-0.15 cSv, i.e. about an order of magnitude lower as compared with public exposures from the Chernobyl accident.

ВВЕДЕНИЕ

Полученные за прошедшие 10 лет после аварии на ЧАЭС результаты обследования загрязненных территорий и здоровья проживающего на них населения позволили установить наличие реальной и мнимой опасности воздействия радиационного фактора на большое количество людей.

Радиационное воздействие на население Российской Федерации имело место не только после аварии на ЧАЭС, но и после проведения ядерных испытаний в атмосфере на Семипалатинском и Новоземельском полигонах. Население, по воле судьбы оказавшееся вовлеченным в радиационную ситуацию, чаще всего видело выход из этого положения в реализации требований на социальную помощь, льготы и компенсации часто независимо от степени реальной опасности.

Основной задачей сообщения является сопоставление возможных индивидуальных и коллективных доз внешнего облучения населения различных регионов Российской Федерации после проведения ядерных испытаний в атмосфере с аналогичными дозами облучения населения после аварии на ЧАЭС.

1. ОБЛУЧЕНИЕ НАСЕЛЕНИЯ В РЕЗУЛЬТАТЕ АВАРИИ НА ЧАЭС

К исходу 1990 г. после проведения дополнительных работ по определению плотностей загрязнения местности после аварии на ЧАЭС стала возможна реальная оценка масштабов радиоактивного загрязнения территории Российской Федерации цезием-137 с плотностью, превышающей 1 Ки/кв.км (37 кБк/кв.км). Кроме того существенно, по сравнению с более ранними оценками, были уточнены представления о зоне с плотностью загрязнения 15-40 Ки/кв.км (555-1500 кБк/кв.км). В настоящее время в России на загрязненной территории проживает около 2 млн. человек [1].

На основании результатов анализа данных, имеющихся в литературе, и расчетов с использованием работ [2-4] проведена оценка доз внешнего облучения населения различных регионов Российской Федерации после возникновения ряда радиационных инцидентов (радиационных аварий и испытаний ядерного оружия). При этом исходили из предположения, что доза внешнего облучения населения является основным показателем наличия радиационной опасности для его здоровья [5].

В таблице 1 представлены результаты расчета ожидаемых доз внешнего облучения населения, длительно (до 50 лет) проживающего в зонах радиоактивного загрязнения, которые образовались на территории Российской Федерации после аварии на ЧАЭС.

Основными данными табл. 1 являются максимально возможная доза внешнего облучения населения, проживающего на загрязненной территории, средняя индивидуальная доза и ожидаемая коллективная доза. Все значения доз оценены для продолжительности проживания в течение 50 лет на загрязненной местности . Чем больше разница между максимальной и средней дозами. тем меньшая доля для населения облучается дозами. величины которых приближаются к максимальной дозе. Условно можно считать. что если величина коллективной дозы характеризует общие масштабы загрязнения. то средняя доза - условную степень опасности (радиационного риска). Приведенные выше величины доз предполагается сопоставить с аналогичными показателями, определяющими характер последствий для населения испытаний ядерного оружия в атмосфере на полигонах бывшего СССР.

Таблица 1. Ориентировочные данные о дозах внешнего облучения населения, проживающего в течение 50 лет в зонах радиоактивного загрязнения, которые образовались после аварии на Чернобыльской АЭС

Регион	Количество населения, проживающего на загрязненной территории, тыс. чел.	Максимальная доза внешнего облучения, сЗв	Средняя доза внешнего облучения населения, сЗв	Коллективная доза внешнего облучения, тыс.чел. х Зв
ОБЛАСТИ:				
1.Брянская	515	40	3,6	20
2.Тульская	700	15	1,7	12
3. Орловская	352	15	1,05	3,7
4.Калужская	168	12	1,5	2,5
5.Рязанская	203	10	1,4	2.8
6,Белгородская	102	7	1,25	1,3
7.Липецкая	96	6	1,25	1,2
8.Курская	61	5	1,25	0,75
9.Пензенская	45	5	1,25	0,55
10.Тамбовская	24	5	1,25	0,30
11.Воронежская	37	5	1,2	0,45
12.Ленинградская (без областного центра)	15	5	1,35	0,20
13.Ульяновская	7	5	1,45	0.10
14.Смоленская	5	5	1.50	0,75
15.Республика Мордовия	20	5	0,5	0,10
ВСЕГО	**2350**	**-**	**2,0**	**47,15**

2. ПОСЛЕДСТВИЯ ЯДЕРНЫХ ИСПЫТАНИЙ В АТМОСФЕРЕ

В период проведения испытаний ядерного оружия в атмосфере (1949-1962 гг.) на Семипалатинском и Новоземельском полигонах были осуществлены 31 наземный и 175 воздушных ядерных взрывов Основные данные о ядерных испытаниях на этих полигонах приведены в табл. II.

Известно, что наиболее значительное радиоактивное загрязнение местности происходит на локальных следах , образовавшихся после наземных ядерных взрывов. На Новоземельском полигоне был произведен только один наземный взрыв (на башне высотой 15 м). все остальные - на Семипалатинском полигоне, после осуществления которых сформировались локальные следы с различной степенью радиоактивного загрязнения местности.

Характерной особенностью проведения ядерных испытаний является то, что практически с первого ядерного взрыва 29.08.49г. в стране начала создаваться система контроля за радиационной обстановкой на территориях, расположенных за пределами зоны Семипалатинского полигона. Радиационная разведка на следе первого ядерного взрыва проводилась на расстояниях до 700 км от центра взрыва в направлении Курья-Бийск, т.е. почти до северо-восточной границы Алтайского края [8,9].

Таблица II. Сведения о ядерных испытаниях на полигонах бывшего СССР [6, 7]

Вид испытания (взрыва)	Семипалатинский полигон			Новоземельский полигон		
	Количество испытаний (взрывов), шт	Тротиловый эквивалент, Мт	Количество цезия-137 выброшенного в атмосферу, Бк	Количество испытаний (взрывов), шт	Тротиловый эквиваент, Мт	Количество цезия-137 выброшенного в атмосферу, Бк
Воздушный (без высотных взрывов)	93	2,7	$3*10^{15}$	85	240	$3*10^{17}$
Наземный	30	3,6	$4*10^{16}$	1	0.032	$4*10^{13}$
Надводный	-	-	-	2	0.2	$4*10^{14}$
Подводный	-	-	-	3	0,2	-
Подземный	328	10,2	$3*10^{15}$	42	23	$5*10^{13}$
ВСЕГО	**451**	**~ 16,2**	**$\sim 4,5*10^{16}$**	**133**	**~263**	**$\sim 3*10^{17}$**

Одной из форм контроля было проведение комплексных обследований загрязненных территорий. Это позволило вести динамическое наблюдение за радиационной обстановкой и состоянием здоровья населения, проживающего в зонах радиоактивного загрязнения. Активное участие в проведении обследований принимали специалисты бывшего 3-го Главного управления при Минздраве СССР. Госкомгидромета СССР и др.

Для объективной оценки степени влияния ядерных испытаний на здоровье населения сотрудниками Института биофизики была проведена большая работа по сбору. анализу и обобщению архивных материалов, содержащих данные радиационной разведки и другие сведения о радиационных следах вокруг Семипалатинского полигона с дозой излучения до полного распада РВ, превышающими 0,1-0,5 сЗв.

На основе этих материалов была составлена база архивных данных и альбом следов радиоактивного загрязнения (рис. 1). Достаточно надежные данные о дозах облучения населения, проживающего в зоне влияния ядерных испытаний на Семипалатинском полигоне. представлены в материалах. которые подготовлены по программе “Семипалатинский полигон - Алтай” [10-16].

Архивных материалов с результатами радиационной разведки после испытаний ядерного оружия на Новоземельском полигоне значительно меньше. Связано это с особенностями проведения ядерных испытаний на Новоземельском полигоне, заключающимися, прежде всего в том, что на нем осуществлялись в основном мощные высокие воздушные взрывы в “бомбовом” режиме (бомбометание с самолета) . Однако есть много сведений о содержании РВ в объектах внешней среды (почва, мох, снег и др.) об интенсивности радиоактивных выпадений в регионах Арктики, Западной и Восточной Сибири, Дальнего Востока. Эти сведения собраны сотрудниками метеостанций и специальными экспедициями Госкомгидромета СССР. а также организациями и санитарно-эпидемиологическими станциями Минздрава СССР.

В табл. III представлены данные о количестве ядерных испытаний по годам, которые проводились на Новоземельском полигоне до их запрещения (1963г.) в трех средах: в космосе, атмосфере и воде.

Таблица III. Количество ядерных испытаний по годам, которые проводились на Новоземельском полигоне в 1955-1962гг., и их тротиловый эквивалент

Наименование параметра	Годы								
	1955	1956	1957	1958	1959	1960	1961	1962	Всего
Количество испытаний (взрывов)	1	0	4	23	0	0	26	36	90
Тротиловый эквивалент (суммарный), Мт	0,0035	0	4,4	12,6	0	0	83	140	240

На Новоземельском полигоне были осуществлены самые мощные воздушные взрывы не только в СССР, но и во всем мире. Из 85 воздушных взрывов 36 имели тротиловый эквивалент от одной Мт и более. Один взрыв имел мощность около 50 Мт (30.10.61г.) и 4 взрыва примерно по 20Мт. После двухлетнего моратория (1959-1960гг.) были проведены две самые крупные серии испытаний. Первая серия - с 10.09.61г. по 04.11.61г. и вторая серия - с 05.08.62г. по 25.12.62г. Во всех испытаниях с 21.09.55г. по 25.11.58г. мощность взрывов была почти в 15 раз меньше , чем в последующих двух сериях. Поэтому с вкладом проводившихся до 1958 г. испытаний в радиоактивное загрязнение окружающей среды практически можно не считаться.

При проведении первой, короткой по времени, серии испытаний дул устойчивый ветер в южном и юго-восточном направлениях, а во время проведения второй серии, которая была более длительной и характеризовалась межсезоньем, перенос воздушных масс происходил в различных направлениях.

Проведение ядерных испытаний на Новоземельском полигоне имело свои очень важные особенности. Во-первых, основная часть РВ в следствие большой высоты стабилизации облаков взрывов находилась выше тропопаузы, которая является задерживающим слоем, препятствующим оседанию мелких радиоактивных аэрозолей и обмену воздушных масс между стратосферой и тропосферой. Во-вторых, следует отметить важную роль фракционирования, и поэтому мало интенсивные тропосферные выпадения были обеднены биологически опасными радионуклидами (изотопами йода, цезия и стронция), о чем свидетельствуют все экспериментальные данные. В-третьих, внутреннее облучение населения обусловили глобальные радиоактивные выпадения, которые преимущественно содержали основные дозообразующие и долгоживущие радионуклиды. Глобальные выпадения были причиной радиоактивного загрязнения окружающей среды и дополнительного облучения населения всей Земли (преимущественно Северного полушария).

Высотное зондирование показывало, что РВ была загрязнена вся арктическая атмосфера. В течение зимы 1961-1962 гг, наблюдалось постепенное снижение высоты слоя максимальной концентрации РВ с 30 км в декабре 1961 г. до 23 км в феврале 1962 г. и даже до 20 км - к концу первой половины 1962 г.

С использованием экспериментальных данных рассчитаны значения доз гамма-излучения на местности до полного распада РВ после проведения всех ядерных испытаний в атмосфере на Новоземельском полигоне (рис.2).

На основании данных, приведенных на рис. 1 и 2, выполнены расчеты ориентировочных величин доз внешнего облучения населения некоторых регионов Российской Федерации, расположенных в зонах влияния ядерных испытаний на Новоземельском (Северном) и Семипалатинском полигонах. Результаты этих расчетов сведены в табл. IV. И хотя ядерный воздушный взрыв мощностью 40 кт на войсковых учениях в Тоцком не считается ядерным испытанием и проведен вне специализированного полигона, однако для него также представлены данные о максимальной, средней и коллективной дозах внешнего облучения населения.

Некоторые регионы, например, Красноярский край, Томская, Иркутская, Читинская области и др. расположены в зонах влияния испытаний, проводившихся на обоих ядерных полигонах.

Представляет интерес провести сопоставление и обсуждения полученных результатов.

3. ОБСУЖДЕНИЕ ПОЛУЧЕННЫХ РЕЗУЛЬТАТОВ

Из данных, приведенных в табл.IV, следует, что размеры зоны влияния ядерных испытаний на Новоземельском полигоне значительно больше, чем на Семипалатинском полигоне. Радиоактивным выпадениям "северных" испытаний с дозой превышающей фоновые значения в два раза подвергалось практически 2/3 малонаселенной части территории России, на которой проживает примерно 35 млн. человек. Однако максимальные и средние дозы внешнего облучения относительно невелики (от 0,001 до 2 сЗв) при достаточно большой коллективной дозе (около 50 тыс.чел. х Зв). Это вполне возможный эффект после осуществления высоких воздушных ядерных взрывов большой мощности.

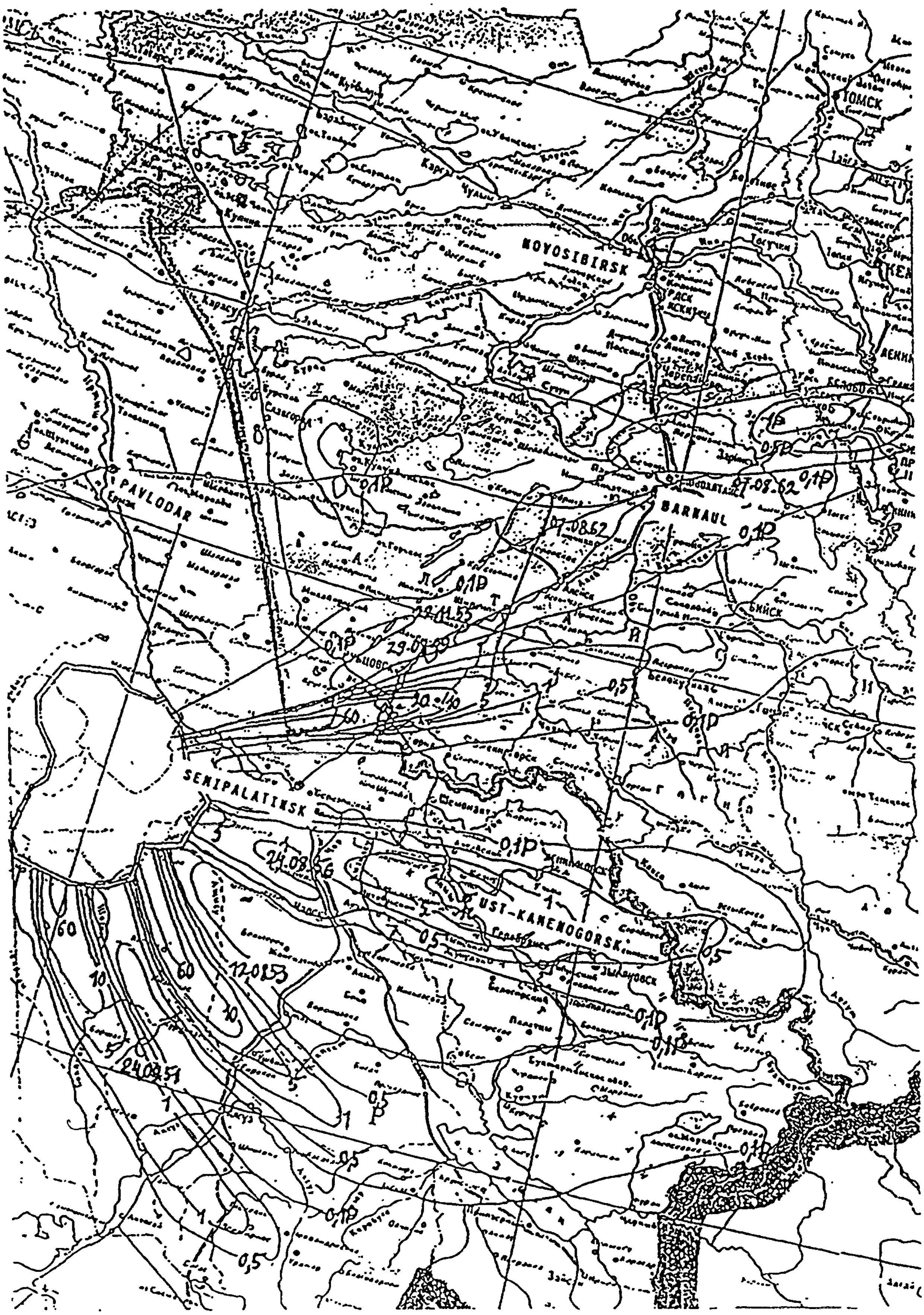

Рис. 1.

Map showing the location of traces of radioactive contamination beyond the boundaries of the restricted area of the Semipalatinsk test site which caused maximum radiation exposure of the population in the areas adjacent to the site. The map shows the dates of the explosions and the position of isolines with the external gamma ray dose values in roentgens for open areas prior to complete decay of the radioactive substances (scale 1:4 000 000). The unit 'P' is equivalent to a roentgen.

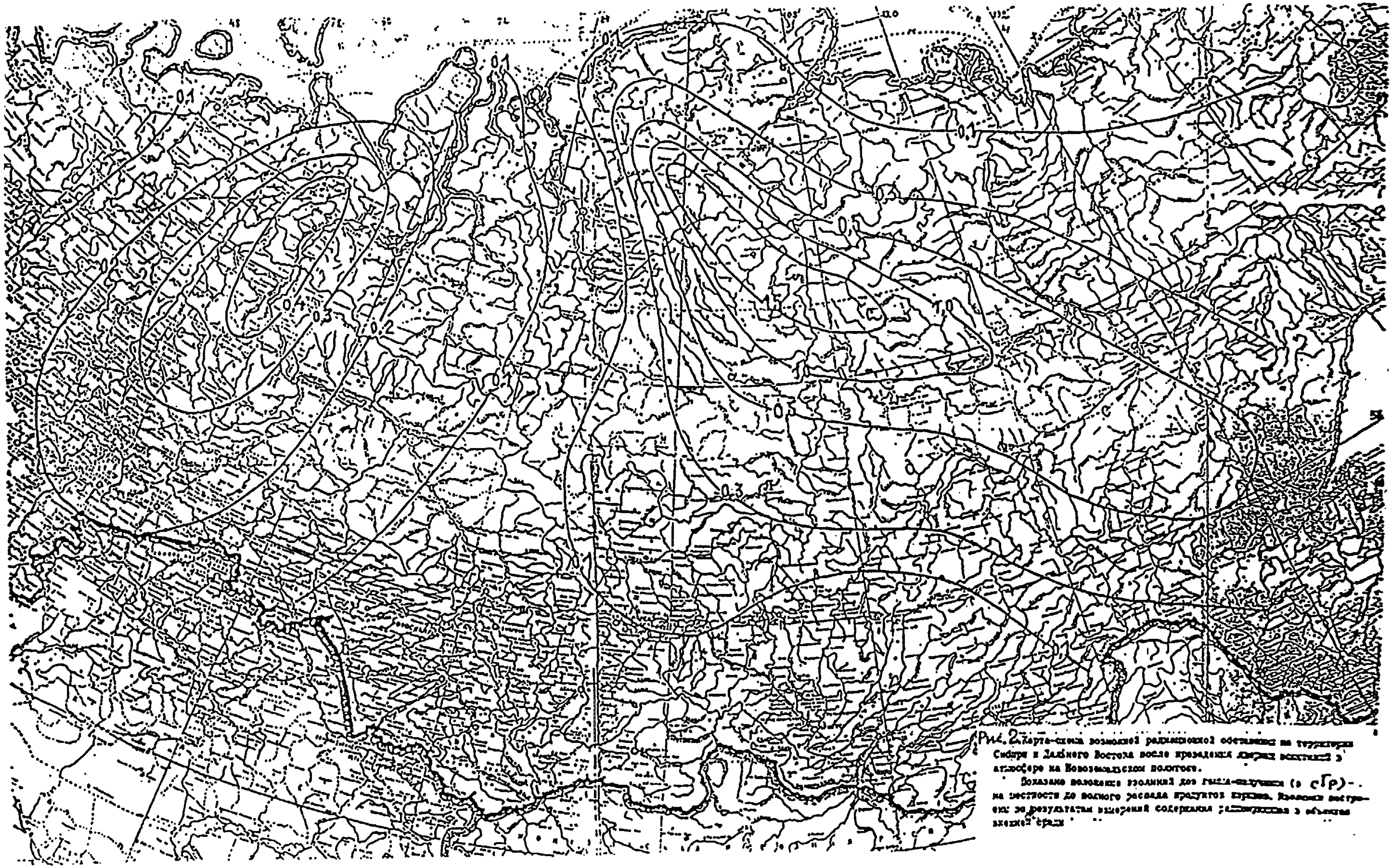

Рис. 2. Карта-схема возможной радиационной обстановки на территории Сибири и Дальнего Востока после проведения ядерных испытаний в атмосфере на Новоземельском полигоне.

Показано положение изолиний доз гамма-излучения (в сГр) на местности до полного распада продуктов взрыва. Изолинии построены по результатам измерений содержания радионуклидов в объектах внешней среды

Таблица IV. Ориентировочные данные о дозах внешнего облучения населения (до полного распада РВ) различных регионов Российской Федерации в зонах влияния ядерных испытаний

Регион	Удаление от полигона тыс.км	Количество населения, проживающего на загрязненной территории, тыс.чел.	Максимальная доза внешнего облучения, сЗв	Средняя доза внешнего облучения населения региона, сЗв	Коллективная доза внешнего облучения, тыс.чел.х Зв
1. ЗОНА ВЛИЯНИЯ ИСПЫТАНИЙ НА СЕВЕРНОМ ПОЛИГОНЕ					
1.Красноярский край (без автоном. округов)	1,3-3,0	2693	0,7	0,10	3
2.Таймырский (Долгано-Ненецкий АО)	0,9-2,2	48	2	1,0	0,5
3.Эвенкийский АО	1,6-2,4	17	1,5	0,7	0,12
4.Республика Саха (Якутия)	2,0-3,7	883	1	0,8	7
5.Тюменская область (без автоном. округов)	1,8-2,2	1165	0,3	0,15	1,8
6.Ямало-Ненецкий АО	0,5-1,8	193	0.4	0,13	0,25
7.Ханты-Мансийский АО	0,9-1,9	673	0,3	0,17	4,9
8.Пермская область (без автоном. округов)	1,3-2,0	2830	0,3	0,17	4,9
9.Магаданская область вместе с Чукотским АО	3,8-4,5	490	0,6	0,25	1,2
10.Республика Коми	0,8-1,6	1147	0,4	0,17	2
11.Хабаровский край	3,6-4,5	1610	0,6	0,2	3,2
12.Ненецкий АО Архангельской области	0,4-0,8	50	0,3	0,10	0,5
13.Удмурдская Республика	1,7-2,0	1516	0,2	0,11	1,6
14.Свердловская область	1,4-2,0	4500	0,3	0,20	9,5
15.Курганская область	2,0-2,2	1085	0,2	0,14	1,5
16.Челябинская область	2,0-2,4	3480	0,2	0,14	4,8
17.Республ. Башкортостан	2,0-2,4	3865	0,2	0,10	4
18.Омская область	1,9-2,4	1963	0,15	0,10	2
19.Республика Татарстан	1,9-2,2	3453	0,15	0,06	2,4
20.Иркутская область	2,6-3,4	2616	0,3	0,005	0,8
21.Читинская область	3,4-3,9	1258	0,2	0,001	0,15
ВСЕГО	-	35535	-	0,15	52,27
2. ЗОНА ВЛИЯНИЯ ИСПЫТАНИЙ НА СЕМИПАЛАТИНСКОМ ПОЛИГОНЕ					
1.Алтайский край	0,14-0,7	2514	52	0,5	13,5
2.Республика Алтай	0,4-0,8	174	0,5	0,2	0,3
3.Республика Хакассия	0,7-1,0	508	0,2	0,15	0,76
4.Новосибирская область	0,5-0,7	2657	1	0,05	1,44
5.Кемеровская область	0,7-1,0	2990	1	0,06	1,64
6.Красноярский край	0,9-2,2	600	0,12	0,04	0,24
7.Иркутская область	1,3-2,7	1340	0,1	0,04	0,47
8.Читинская область	2,0-3,0	1258	0,05	0,04	0,44
9.Томская область	0,7-1,3	887	0,15	0,04	0,35
ВСЕГО	-	15928	-	0,12	19,14
3. ЯДЕРНЫЙ ВЗРЫВ НА ТОЦКИХ УЧЕНИЯХ					
1.Ближняя зона (Оренбургская область)	0-0,2	20	1	0,3	0,065
2.Дальняя зона (Красноярский край)	1,5-2,1	150	0,12	0,05	0,081
ВСЕГО	-	170	-	0,08	0,146
ИТОГО		51633		0,14	71,6

Зона влияния ядерных испытаний на Семипалатинском полигоне, как по количеству проживающего на ее территории населения, так и по величине коллективной дозы примерно в два раза меньше. В этой зоне следует отметить большую величину максимальной дозы внешнего облучения до полного распада РВ (52 сЗв) для сел Наумовка и Топольное в. Угловском районе Алтайского края. Средние дозы облучения примерно одинаковы в зонах влияния ядерных испытаний обоих полигонов.

Ядерный взрыв на Тоцких учениях практически ничего к этому добавить не мог.

Значительные трудности вызывает сопоставление данных, характеризующих последствия аварии на ЧАЭС и ядерных испытаний, т.е. данных, содержащихся в табл. I и IV. Это связано с отсутствием обоснованных методик. Однако попытаемся осуществить такое сопоставление.

Первое, на что нужно обратить внимание, так это на большую разницу в сроках накопления доз облучения. Для продуктов аварии ядерного реактора - это практически вся продолжительность человеческой жизни, а для продуктов ядерного взрыва - не более 1-2 лет.

Далее следует отметить, что приведенные в табл. IV данные носят пока ориентировочный характер. Они могут еще изменяться, но незначительно.

Важный вывод из проведенного исследования состоит в том, что ядерные испытания на Новоземельском полигоне не создали таких плотностей радиоактивного загрязнения на локальных следах ядерных взрывов, какие могли бы стать причиной для компенсационных выплат и льгот.

Если сравнение данных табл. I и IV провести по величинам средних доз внешнего облучения населения, проживающего на загрязненной местности (что вполне допустимо при отсутствии больших градиентов в распределении по площади регионов плотностей загрязнения местности и доз излучения), то последствия аварии на ЧАЭС займут лидирующее положение. Об этом свидетельствует большая величина коллективной дозы (около 47 тыс.чел. х Зв.) для населения 2,3 млн. человек.

ВЫВОДЫ

1. Проведено обобщение большого объема материала с данными о радиационной обстановки в зонах влияния ядерных испытаний на Семипалатинском и Новоземельском полигонах, а также влияния других радиационных инцидентов, имевших место на территории Российской Федерации. Создана объемная база архивных данных с результатами радиационных разведок в зонах радиоактивного загрязнения.
2. Выполнены расчеты доз внешнего облучения населения в зонах влияния ядерных испытаний. Для ядерных испытаний, проведенных на Новоземельском полигоне, осуществлен анализ особенностей формирования радиоактивного загрязнения окружающей среды и показано, что основным транспортным путем РВ к поверхности Земли являлись глобальные выпадения.
3. Сопоставление данных о дозах возможного облучения населения после аварии на ЧАЭС и после ядерных испытаний в атмосфере, свидетельствует о том, что авария на ЧАЭС занимает лидирующее положение.

Целесообразно разработать методику сравнения степени опасности различных радиационных инцидентов как по радиационным характеристикам, так и по медицинским последствиям.

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THE CHERNOBYL RADIOECOLOGY CONSEQUENCES FOR THE RUSSIAN ARCTIC

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The Northern radioecological chain "lichen - reindeer - man" has been studied extensively. As seen from Table I, this chain at the territory of the Russian Arctic is essentially cleared of Cs-137 and Sr-90 global fallouts. Beginning from 1986, the radioactivity clearance in Murmansk and Nenets regions has become slower due to the contaminations by radioactive caesium of the Chernobyl origin. Contents of caesium-134 (Chernobyl's marker) in lichen vary from 10 to 15 Bq/kg, in reindeer meat - from 16 to 40 Bq/kg (data from 1991-1992) [1].

Table I

Caesium-137 (numerator) and Strontium-90 (denominator) mean concentration and ratio in food chain (1961-1992), Bq/kg.

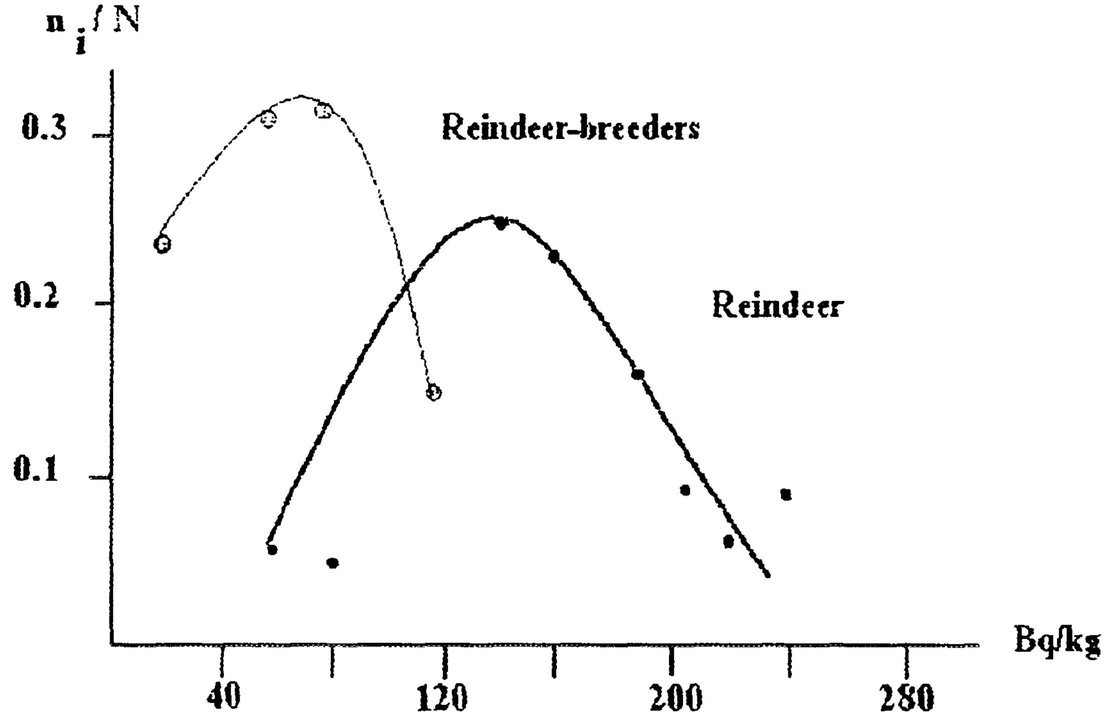
Region	Lichen				Reindeer				Man			
	1961-1983		1991-1992		1961-1983		1991-1992		1961-1983		1991-1992	
	1*	2*	1	2	1	2	1	2	1	2	1	2
Murmansk	814/296	3/1	222/12	18/1	1480/2966	1/2	300/40	7.5/1	888/104	9/1	77/8	8/1
Nenets	814/222	4/1	248/20	20/1	1000/1520	1/1.5	330/51	6.5/1	481/98	5/1	60/8	8/1
Komi	814/222	4/1	96/17	6/1	1000/1520	1/1.5	90/35	2.5/1	481/98	5/1	32/7	4.5/1
Chukotka	370/185	2/1	56/20	3/1	555/1500	1/3	80/60	1.3/1	518/100	5/1	22/7	3/1

* 1- mean concentration Cs^{137}(muscles) and Sr^{90} (bones)
2- them ratio

The recent investigations carried out during joint Russian - Finnish expedition at the Kola peninsula (1994 - 1995) confirmed the earlier results. Mean concentrations of Cs^{137} in lichen collected in Lovozero were found to be 290±60 Bq/kg of dry weight and that of Cs^{134} - 8.5±5.6 Bq/kg. The amount of Cs^{137} deposition was estimated to be 1000±360 Bq/m^2. Mean concentration of Cs^{137} in reindeer meat from Lovozero was found to be 390±60 Bq/kg of fresh weight and that of Cs^{134} - 7.6±2.0 Bq/kg, respectively. When calculated from these mean results and assuming that in May 1, 1986, Cs^{134}/Cs^{137} ratio was 0.55, about 40% of the Cs^{137} activity originated from the nuclear weapons tests and 60% was due to the Chernobyl accident [2].

Radioecological situation in the Western part of Nenetsk region and of region Arkhangelsk was studied in summer 1993 at zone of reindeer-breeding. Increased radiocaesium concentration from 600 to 1200 Bq/kg was discovered in the meat of winter reindeers. Whole-body measurements on reindeer-herders, reindeer-breeders and environmental analyses were performed during two summer expeditions. The functions of radiocaesium specific activity distribution on the body of reindeer-breeders (solid line) and of the reindeers (dotted line) were constructed (Fig.1).

Fig.1 The function of radiocaesium specific activity distribution.



n_i - number of reindeers (reindeer-reindeer-breeders) with *i* radiocaesium specific activity

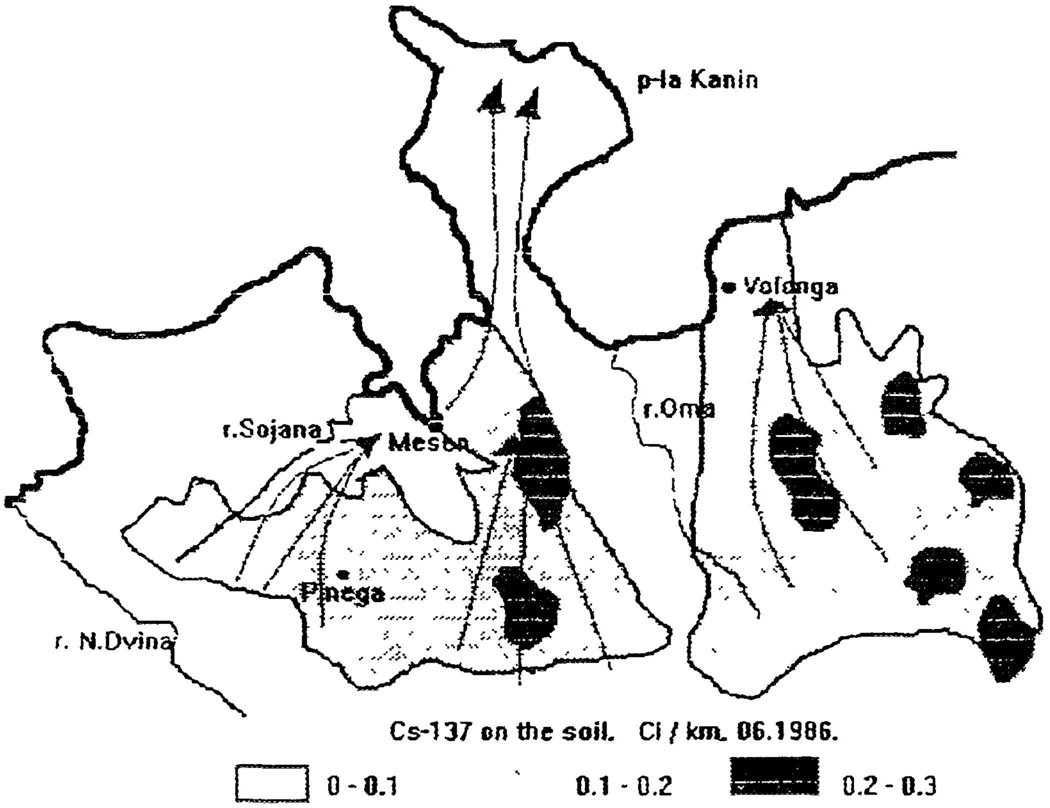
N - general quntity of reindeers (reindeer-breeders) which were measured at the same time.

The ratio of maximum of this distributions for the reindeer-breeders and reindeer was correspondingly 1:2. This ratio well agrees with the earlier obtaineed empirical ratio of radiocaesium specific activity in the body of reindeer-breeders to specific activity of radiocaesium in the reindeers meat.

The territories of this region marked on the map as higher radiocaesium contaminated after the Chernobyl accident (June-July 1986) practically correspond to with the winter pastures or with ways to the summer pastures (Fig.2).

Effective doses for reindeer-bredeers were determined by two different methods: by whole-body measurements and by assessing of reindeer meat consuption (foodchain) (Table II). The results of these independent methods coincide with each other. The summary, fallouts after Chernobyl accident is the cause of increased levels of lichen's and reindeer's radiocaesium in Nenets region [3].

Fig.2 The map of radiocaesium contamination for Nenets and Arhangelsk region.



The appows shows the ways of reindeers migration to summer pastures

Only, the European part of the Russian Arctic was affected by radioactive contamination of the Chernobyl origin, in comparision with to the Arctic territories of east of the Urals.

Table II

Radioecological data and effective doses for reindeer-breeders.
(Data for June 1993)

N bregade	Zone of winter pastures	Concentration of radiocaesium in reindeer-meat, Bq/kg		Effective doses (consumption) mSv/year	Whole-body measurement, Bq/kg	Effective doses (whole-body measurement), mSv/year
		Cs-137	Cs-134			
1.	Sojana-Mesen	250±50	5±2	0.45	150	0.41
2.	Upper r.Oma	220±40	6±2	0.40	155	0.42
3.	Sojana-Mesen	275±70	10±3	0.49	180	0.48
4.	Sojana-Mesen	210±40	7±2	0.37	75	0.20
5.	Vigas-Nes	190±35	8±3	0.34	115	0.32
7.	Piniga-Mesen	120±25	4±1	0.22	55	0.17

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COMPARATIVE ASSESSMENT OF PUBLIC HEALTH DETRIMENT FROM THE CHERNOBYL ACCIDENT AND COUNTERMEASURES

XA9745908

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Population exposure levels and health detriment from all sources of radiation and the Chernobyl accident have been compared and conclusions made on similar or higher health detriment from sources other than these of the Chernobyl origin.

Data obtained cannot define the correlation between health impairment and population radiation exposure levels.

Health detriment assessment has been made for the accident effect as well as for various countermeasures (relocation, decontamination, diet regulations and others). Cost-benefit analysis for averted dose including cost of countermeasures has been applied as a basis for decision-makings and optimization of post-accidental actions. Inconsistency of the experts proposed and real actions caused unjustified substantial expenditure due to non-acceptance of the experts opinion and involvement of some non-professional scientific, administrative and political authorities in planning and implementation of countermeasures.

Collective radiation dose from the Chernobyl accident (120.000 man-Sv) is only 0.3 % of the 70-year summary dose (42.000.000 man-Sv) from all sources of exposure in Russia (Table I). The health detriment from this exposure (stochastic effects) might be evaluated as loss of 120.000 man /years of life, or 8760 radiation-induced cancers and genetic defects, taking into account risk about $7.3 \cdot 10^{-2}$ Sv and equivalent of 1 case to 14-year loss. With general population mortality (16 deaths per 1000 population in 1994 in Russia) equal to 160.000.000 during 70 years, radiation-related mortality might be equal to 0.006 %.

The expenditures for prevention of the expected radiation health detriment during 10 years after the accident were comparable to all Federal budget for public health of 150 million of population of Russia.

Thus, cost of protection of one person from the after-accident radiation was equal to the cost of protection average of 10.000 persons from other health hazards.

It is well- known that the most radical and, at the same time, expensive measure on the population protection in large scale accident is relocation of the population from the radioactively contaminated areas.

A cost-benefit analysis has been carried out on the population relocation from the western areas of the Bryansk region organized between 1989 and 1993. 41 settlement has been chosen for the analysis, with the initial density of the contamination by cesium-137 equal to 30 Ci sq.km. 9485 persons have been the residents of these settlements ~~to the moment of~~ relocation, through the period of relocation a number of them being reduced by 51.5 %.

The performed calculations based on the accepted estimation models of the expected individual effective radiation doses show that the relocation 3-6 years after the Chernobyl accident averts collective effective radiation dose equal to 354 man-Sv. According to the ICRP Recommendations (Publication N 60) it corresponds to 26 cases of stochastic effects.

Economical analysis displays that the expenditure for relocation of 1 person (including cost of the lost property, building of new dwellings in new places of settlement, providing of new working places etc.) 22 times exceeds the cost of all social privileges and compensations for 1 person living in the contaminated area. Expenditure on

Radiological situation in Russia in 1995.

Source of radiation exposure	Number of persons involved (average)	Effective dose		
		Mean individual in 1995, mSv	Dose for life (70 years), mSv	Collective dose for life (70 years) mSv
All sources:	**150.000.000**	**4.0**	**280**	**42.000.000**
natural	**150.000.000**	**2.9**	**200**	**30.000.000**
medical	**150.000.000**	**1.0**	**70**	**10.000.000**
others (fallout, accident etc.)	**150.000.000**	**<0.1**	**<10**	**<1.500.000**
Occupational	**250.000**	**7.0**	**350**	**87.000**
Accidents and Nuclear Weapons tests				
1. Effluents in river Techa	**28.000**	**<1.0**	**200-300**	**7.000**
	2.000		**1000**	**2.000**
2. Accident in Kyshtim	**24.000**	**0.1-0.3**		
	15.000		**15**	**225**
	7.000		**40-120**	**560**
	1.500		**500**	**750**
3. Air contamination from "Majak":				
in Chelabinsk-65	**80.000**		**80**	**6.400**
from Chelabinsk region	**1.100.000**		**27**	**30.000**
4.Chernobyl	**150.000.000**	**<0.1**	**0.8**	**120.000**
Bryansk region	**100.000**	**1.5**	**80**	**8.000**
"Liquidators"	**170.000**	**0.0**	**100**	**17.000**
5. Atomic Weapons tests:				
in Arctic (global) [reindeer herding]	**100.000**	**0.3**	**30**	**3.000**
Altai, Semipalatinsk	**270.000**	**0.0**	**50-250**	**40.000**
	40.000	**0.0**	**≥250**	**≥17.000**

relocation in the named years 40 times exceeds the benefit defined by a monetary equivalent of the averted radiation detriment.

The results of socio-psychological investigation of the relocated people testify that the average anxiety levels ~~among them~~ are higher, but the indices of mood and health state are lower than those in the people who continued to live at the contaminated areas. Nevertheless, at present it is not possible to make quantitative assessment of health detriment caused by socio-psychological consequences for the relocated people.

We suppose that real meaning of the monetary equivalent of the detriment regarding the named consequences would be essentially higher.

Thus, the performed assessment of the relocation effiency reveals an essential prevalence of cost over benefit.

Simple calculation can show that unjustified noneffective expenditure has been made to prevent health detriment instead of investment for general improvement of health care and treatment of patients really suffering from cancer, cardio-vascular and other health disorders.

Hypocritical objection to "unhuman" calculation of the cost of priceless human life creates a real health detriment and danger for human life and social progress. Objective expert assessment of risk and health detriment is obligatory for decision-makings, effective investment into progress of human society.

Validity and value of previously made assessment and prognosis of 1982 Statement of 92 Russian experts, WHO mission and International Chernobyl Project organized by IAEA and others, are proved by the development of the after-Chernobyl reality.

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