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MEDICAL ASPECTS OF THE CHERNOBYL ACCIDENT

PROCEEDINGS OF AN ALL-UNION CONFERENCE
ORGANIZED BY THE
USSR MINISTRY OF HEALTH
AND THE
ALL-UNION SCIENTIFIC CENTRE OF RADIATION MEDICINE,
USSR ACADEMY OF MEDICAL SCIENCES,
AND HELD IN KIEV, 11–13 MAY 1988

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FOREWORD

On 26 April 1986, an accident occurred at Unit 4 of Chernobyl nuclear power plant resulting in the destruction of the reactor core. The causes of the accident as well as its consequences and impact mitigation are the focus of attention of Soviet specialists in radiation protection, nuclear engineering, radiation medicine and ionizing radiation dosimetry.

Information was presented at special meetings held by the IAEA which have intensified its work on radiation standardization and medical intervention planning for nuclear accidents. The Chernobyl accident and its consequences are a matter of interest for research workers from many countries.

National committees on radiation protection are giving special attention to the questions of medical assistance to the injured during a radiation accident, and to the development of information and radiation control systems. Throughout the world, considerabled efforts are being made to solve the problems of further development of nuclear engineering.

From 11 to 13 May 1988, the All-Union Scientific Centre of Radiation Medicine convened a Conference on Medical Aspects of the Chernobyl Accident in Kiev. This was the first conference on this subject with international participation held in the Soviet Union. There were 310 specialists representing Soviet scientific establishments and over 60 experts from 23 other countries and international organizations (IAEA, WHO, ICRP) participated in the Conference. The Conference was widely publicized by the mass media. In all, 86 Soviet and 36 foreign journalists, radio and TV correspondents, including those representing leading scientific journals, were accredited to the Conference.

Participants at the Conference discussed medical aspects of accident mitigation, including therapeutic, psychological, demographic, epidemiological and dosimetric problems. Future research on these and some other issues was considered in detail.

Participants were given the opportunity to visit the Chernobyl site and the town of Slavutich, and to get acquainted with the work of some specialized medical establishments in Kiev.

These Proceedings include 29 reports presented by Soviet scientists during the four sessions as well as summaries of discussions and opening addresses by Mr. E.I. Chazov, Minister of Public Health of the Soviet Union, Mr. H. Blix, Director General of the International Atomic Energy Agency, and Mr. V.A. Zgurskij, Chairman of the Executive Committee at the Kiev City Soviet of People's Deputies.

EDITORIAL NOTE

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OPENING SPEECH

E.I. CHAZOV
USSR Minister of Health

Dear colleagues !

Ladies and gentlemen ! Comrades !

Two years have passed since the tragic events on the Chernobyl Nuclear Power Plant, but up to now the pain experienced by our people does not subside and up to now many people are deeply concerned by the question what are the consequences of this accident for our country and first of all for the health of present and coming generations.

When answering these questions one should point out the unprecedented character and compexity of the situation resulted from the fire on the nuclear reactor and radioactive contamination of relatively large territory. Therefore when speeking about the liquidation of the consequences of Chernobyl accident we generally use the terms " unprecedented ", " for the first time in the world practice ", etc. A need emerged in the large-scale governmental measures, as well as in making the new unpracticed decisions, the use of all the medical experience to protect the population health in contaminated areas. One should admit that not everybody was ready to make these decisions, to say nothing of their realisation. Only efficient and active work of all the sections of the Government Commission on liquidation of the consequences of the Chernobyl accident made it possible to overcome the impact of the tragedy and to prevent its negative effects on population health.

One must say definitely that we can today be certain that there are no effects of Chernobyl accident on human health, and to the great extent due to the selfless work of medical specialists (399 of them were given the Government awards). Medical specialists were in the first ranks of those who came to help the people in danger, they were at the station during the accident.

Much had been done during the evacuation of the population from contaminated areas. The scale of these works is unprecedented. Only in some days after the accident highly qualified examination of the population within the accident zone was organized and medical treatment of those with the diagnosis of acute radiation sickness began. Moreover, the thorough investigations of all the aspects of the desease permitted to reduce the group of patients from 237 to 145. World medicine didn t know such a volume of work before.

During the first few months after the accident the stationary examination was provided for 37,5 thousand people (12,6 thousand of them - children). By the end of I936, 696 thousand people (215 thousand of them - children) were provided with necessary medical treatment. The All-Union distributed clinical-dosimetric register of irradiated individuals was created. It includes more than 600 thousand people, who are now under the special dispensary observation.

With the purpose of scientific and methodical guidance of the activities and generalization of the unique scientific data the All-Union Scientific Centre of Radiation Medicine of the USSR Academy of Medical Sciences and Special Research Institute of Radiation Medicine in Minsk were founded.

The complex of measures undertaken in our country allowed to protect the health of Soviet people from the possible negative radiation effects. The thorough medical examinations did not reveal any deflexions in the health of population. Health protection bodies, special scientific centres and dispensaries continue observation of the population in contaminated areas. Today here, in Kiev the first scientific Conference on the Medical Aspects of consequences of the Chernobyl accident is being opened. More than 150 scientists and specialists of our country, engaged in radiation medicine and radiation protection, and over 60 specialists from 23 countries for the first time will discuss thoroughly all the complex of problems caused by the nuclear reactor accident. The Soviet medical specialists have no reasons to conceal anything on this subject. All the materials on the Chernobyl accident effects on human health are submitted to IAEA and WHO since the first months after the accident. The materials were discussed several times at the expert meetings. Taking into consideration the fact that the Chernobyl accident has cast the light on various global problems of medical science and practice we are sure that the results of this discussion which will become available to the broad public, will be the great contribution to the world medical science. Our experience, which the world medical practice did not know, should become accessible to all the scientists and physicians in the world. Today we must also say that the Chernobyl events manifested the solidarity of medical specialists of the whole world in front of the danger brought by uncontrolled distractive force of atom.

We thank everybody who responded to our trouble, who were with us during the hard months of struggling for life and health of Soviet people. We express our gratitude to dozens, and hundreds of scientists and physicians, representatives of international organizations and firms who offered their help.

The Soviet Union has sufficient potential to solve without asssistance the problems emerging from the Chernobyl accident. But we were glad to recive the offers that were the manifestation of natural impulse of the honest people of the globe, the manifestation of sympathy to our people. 400 years ago John Donn wrote: " ... The death of every man belittles me too, since I`m an entity of all mankind, don`t ever ask: " the bell, for whom it tolls", it tolls for you".

Chernobyl accident has cast the light on another global problem - the danger of mankind extermination in the case of nuclear war. Atomic energy is a two-faced Janus who can bring well-being and prosperity to all the peoples of the world in connection with the development of atomic power engineering, but it also can be a cause of mankind extermination. One should remember that Chernobyl accident and medical-biological problems connected with it can in no way be compared with the consequences of modern nuclear war. That is why we all, physicians, people safeguarding the health and peace of the population of our planet, warmly welcome the Soviet-American agreements on nudlear missiles.

Dear colleagues!

Our Conference is held in Kiev, the population of which had displayed selflessness, high consciousness and organisation in the complicated situation, connected with the Chernobyl accident.

Today, when the worst is over, let me wish happiness, health and prosperity to our amiable hosts. I`d like to express deep gratitude to the Central Committee of the Communist party of Ukraine, to the Counsil of Ministers of the Ukrainian SSR, to the Executive Committee of the City Soviet of People`s Deputies for providing exellent conditions for our Conference. I would like to express my gratitude to General Director of the IAEA Mr. H. Blix for his participation, as well as to the representatives of WHO, all our foreign collegues whose participation will contribute to the success of our work.

ADDRESS TO THE PARTICIPANTS OF THE CONFERENCE

H. BLIX
Director General
International Atomic Energy Agency
Vienna

It is now a little over two years ago that the accident at Chernobyl occurred. When I was there the first time, in a helicopter, shortly after the accident, Soviet experts were just bringing the situation under control with great effort and great skill. When I visited Chernobyl a second time in January 1987, the destroyed reactor had been embedded in concrete and two undamaged reactors had been decontaminated and were again in operation after technical modifications and changes in rules and procedures. The third undamaged reactor, adjacent to the destroyed one, has now been in operation since many months, and I expect to see on this occasion how normal life is being restored in the larger part of the area that was closed and evacuated. The accident was very severe, but the wounds are healing.

No-one can deny that the costs of the Chernobyl accident -- in lives, injury to health, damage to the environment and cost to society -- were high and they were the highest here in the Soviet Union and in the Ukraine and Byelorussia. Thirty-one people died, more than 200 suffered radiation injury, over 100,000 were evacuated and large areas of land were contaminated. Radioactive fallout outside the Soviet Union necessitated protective measures in many contries.

What lessons is the world drawing from this accident ? There are those - and they are not few - who say the lesson is simply that nuclear power must be abandoned. The psychological fallout from Chernobyl was considerable and spread all over the world.

We may point out, of course, that many people who oppose nuclear power do not oppose hydro power, despite the many dam catastrophes with thousands of lives lost. Nor do they oppose coal-fired power, despite the thousands of lives that are lost in mines and the environmental pollution and destruction that has been caused by fossil fuels.

I am not critical of this - our human reactions are not necessarily scientific. They are human. We have been sadly and gradually accustomed to death in coal mines, polluted industrial areas and the drowing of people by dams that burst. We have not been accustomed to death and injury by radiation and pollution by radioactive fallout.We must do all in our power to prevent that we get used to it. But we must also avoid letting the spontaneous reactions lead us to act in an unwise and irrational manner. Many people are scared when airplanes take off. But they do fly, because they want to get to the destination; they know that the risks are small and that alternative ways of travelling are also not without risk.

No way of producing electricity is without some risk. It is meaningless to examine only the risks of nuclear power. We must compare these risks with those which we run if we produce a given quantity of electricity by coal or hydro, oil or gas. In a period when it is becoming evident that the environmental consequences of the world's enormous use of fossil fuels are catastrophic regionally and globally - acid rains, dead forests and lakes, and probably a modification of the temperature of the earth's atmosphere, it would be paradoxical to abandon nuclear power, which is not contributing to any of these ills.

The first lesson of Chernobyl is not, therefore, to stop the nuclear power stations, but to reduce further the rists. The public is less tolerant of nuclear accidents than of other accidents.

This has to be accepted by the nuclear industry and regulators everywhere. Safety is never a static concept. Whether in cars, airplanes or nuclear power plants, it can and must always be strengthened. These efforts go along two lines: to prevent accidents and to reduce the size and consequences of such accidents as nevertheless occur.

Each government, of course, is responsible to its own population for the safety of its nuclear installations and it has all the legislative and executive power to exercise that responsibility. However, each government is interested in the nuclear safety in other countries as well and is interested in learning as much as possible from other countries' experience. It is for these reasons that governments are making increasing use the International Atomic Energy Agency. The first requirement is a mutual openness and helpfulness.

An excellent example was set by the Soviet Union, when after the Chernobyl accident it produced an extensive report on the causes and course of the accident and submitted it to international discussion with some 500 nuclear experts in Vienna in August 1986. We regret today the untimely death of Valeri Legasov, who stood with several Soviet colleagues at the centre of this discussion which enabled the nuclear world to learn from the tragic experiences of Chernobyl.

Many measures have since been taken jointly at the IAEA to further strengthen nuclear safety. The Incident Reporting System allows government and nuclear operators to learn from many smaller accidents and incidents that occur. These lessons help to reduce the risk of the bigger accidents. Nuclear Safety Standards (NUSS) are internationally accepted safety standards, and they have now been updated in the light of the Chernobyl experience. A special advisory group consisting of some of the world's best expertise in nuclear power safety - including Mr. V.A. Sidorenko from the Soviet Union - has worked out a set of basic and coherent safety principles which should gradually help to further strengthen safety. And a practice has developed under which Member governments invite the IAEA to send and international team of experts in operational safety to examine an review the operational safety in nuclear power stations on their territory. We have sent some 25 such missions (OSARTs) around the world, breaking the isolation of power plant operators, acquainting them with good practices in other countries, and learning from them as well. I am glad to say that the Soviet Union has invited such a team to come to a plant in your country, just and the US, France, Japan, the Federal Republic of Germany and many other countries have done.

While international efforts to further strengthen operational safety to prevent accidents was one important cosequence of Chernobyl, others were directed at mitigating the size and consequences of accidents that might nevertheless occur. Two conventions were elaborated in record time in 1986, one on early notification to other countries in the event of an accident, to enable them to take precautions against possible transboundary fallout; the other one on emergency assistance to facilitate outside assistance in case of nuclear damage.

One of the lessons taught by Chernobyl accident was that some common standards were desirable regarding the levels of radiation at which different types of food were to be prohibited for consumption:intervention levels. There were wide and unjustified variations in the standards adopted by different countries - many of them quite unnecessarily restrictive. The Codex Alimentarius Commission of the U.N.'s Food and Agriculture Organization (FAO) and the World Health Organization (WHO) is expected to come up with recommendations this summer.

Other important lessons to draw from Chernobyl are those with which your medical profession is concerned. The IAEA's activities in these areas did not start with Chernobyl.

In the field of diagnosis of overexposures, the Agency has had a long-standing activity in biological dosimetry. A report on chromosomal aberration analysis for dose assessment was published immediately after the Chernobyl accident. A new report is in preparation as a result of the advice which the Agency received from a group that met in Leningrad in December 1987. It will be a joint publication by many authors, including several Soviet scientists. It will contain all the biological, biophysical, immunological, biochemical and haematological methods for dose assessment which are presently available.

The Agency has also worked very extensively in the field of medical handling of overexposed persons. A report on the general principles of diagnosis, prognosis and treatment of overexposed individuals is in print and guidelines on the handling of individuals subject to external irradiation and to internal contamination are in a very advanced stage of preparation. A document on skin lesions produced by irradiation is about to be published; it includes substantial contributions by Soviet scientists as a result of the Chernobyl experience.

Let me also mention a very widely disseminated Agency publication, the technical document on " What a General Practitioner (M.D.) Should Know about Medical Handling of Overexposed Individuals". This is not a document for a specialist, but is intended for non-specialized medical practitioners. It has been up-dated after Chernobyl. This publication has been reprinted five times already, and 5,000 copies have been distributed throughout the world. German, Italian and Japanese translations have been completed, and other translations are being prepared. It is now being supplemented with additional documents directed to specialists.

Lastly, let me mention the enormously important epidemiological study of the radiation effects on the population around Chernobyl which the Soviet authorities have launched, and in which they have invited international participation and advice. The IAEA and the WHO have been channels for this international co-operation and the scientific community around the world will welcome the results of this study in an area in which we - fortunately- have limited information.

We know the enormous work which has been performed by the Soviet authorities and institutes to treat and check the people who received or were feared to have been exposed to radiation in the accident. Almost a million members of the public have had various examinations, and the new All-Union Centre of Radiation Medicine of the USSR Academy of Medical Sciences has been established here in Kiev.

Let me close by expressing my thanks to the Soviet Ministry of Health for holding this All-Union Conference, and for having invited more than one hundred scientists from abroad, including a delegation from the IAEA. This will ensure that the conclusions you draw will benefit the maximum number of people around the world. Through the openness you demonstrate, the tragic experience of Chernobyl will expand our knowledge and help us to reduce harmful consequences of radiation. I wish you a very successful conference.

ADDRESS TO THE PARTICIPANTS OF THE CONFERENCE

V.A. ZGURSKIJ
Chairman of the Executive Committee
at the Kiev City Soviet of People's Deputies

Dear participants and guests of the Conference !
Ladies and gentlemen !
Comrades !

On behalf of the Kiev Executive Committee at the City Soviet of People's Deputies I heartly welcome you here in Kiev at the All-Union Conference on the Medical Aspects of the Chernobyl Accident.

Our city, which stands on the bank of the Dnieper, has been chosen for this grand scientific forum, and, we concider it both as a high honour and logical consequence too. Due to the proximity of the Ukrainian capital to the hypocenter of the Chernobyl accident, its large scientific and technical potential, Kiev has become one of the first lines of overcoming the accidental consequences. In those hard months of 1986 the leading experts of our city contributed much to curb the raging atom. Citizens of Kiev were selflessly working to stabilize the situation and to safeguard people's health. All medical staff bore a great responsibility at that time acting all over accidental and neighbouring areas till the first aid was given to the injured. We are grateful to our colleagues from Moskow, Leningrad and other cities of the country for their tireless activity and help. Scientists and public figures from foreign countries have also offered their assistence.

As you know, the All-Union Scientific Center of Radiation Medicine of the USSR Academy of Medical Sciences is founded for the development of long-term strategy of medical measures aimed at the mitigation of the accidental consequences, as well as at the total safety of nuclear engineering. These are the preconditions for the Kiev Conference. In fact, the participation of representatives of international organizations, prominent foreign and Soviet scientists as well as mass media's attention will make the present Conference one of the most important scientific workshops of the final quarter of our century. The public of Kiev have done their best for the success of your scientific and social work, so that you can see an ancient and ever-young Kiev. You arrived here at the days, called by the known writer Michael Bulgakov " chest-nut trees and May on the boulevard". You will see the Dnieper " which is marvelous at shiny weather" as the great Gogol described it. You will see numerous monuments that are 15 centuries old, among them - Kiev -Pechersk and St. Sophia museums that are being now, on the eve of the remarkable historical date, the Millenium of Russian Cristianity, the symbol of centuries-old development of our history and culture.

Success to your Conference, and thank you for your time.

GENERAL ASPECTS OF HEALTH PROTECTION IN THE EVENT OF A NUCLEAR ACCIDENT

MEDICAL AND SANITARY MEASURES TAKEN TO DEAL WITH THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT

G.V. SERGEEV

Abstract

Work was carried out on two fronts: emergency qualified medical aid was organized for those suffering from thermal burns and radiation injuries, and wide-scale prophylactic measures were taken to prevent exposure to radiation and its consequences. More than 600 000 people (including 215 300 children) underwent extensive medical examinations. For prophylactic purposes and in order to diagnose more accurately various diseases which had been identified during the medical surveys, 37 500 people (including 12 600 children) were examined in hospital. (This figure also includes people who made personal requests for such examinations.) No abnormalities associated with exposure to radiation were found. At the suggestion of the USSR Ministry of Health, more than 350 000 children and pregnant women were sent to sanatoriums, rest homes and pioneer camps in 1986-87.

The exposure dose to the population as a result of the Chernobyl accident during the next 50-70 years will not exceed more than 20-30% of the dose from natural radiation.

The accident at the Chernobyl Nuclear Power Plant is the most serious one in nuclear power development. The results of this really gigantic and effective work to eliminate the consequences of the accident have no equal. Therefore the experience has great importance not only for the Soviet, but also for the world science and practice.

The objective of our conference is to highlight medical aspects of the Chernobyl accident. We have to consider thoroughly the events and features related with the accident, the effects of exposure and the contamination of environment. We have also to evaluate the whole amount and quality of work done by medical personnel, the state of health of the exposed group and to consider the long-term objectives of medicine, bearing in mind the consequences of the accident.

Government Medical Commission was established to coordinate the activities of all medical expert groups working on the elimination of the consequences of the accident at the Chernobyl Nuclear Power Plant. The leaders of the USSR Ministry of Public Health and the most prominent scientists in the field of radiological medicine, as well as representatives of a number of other organizations were included in this Commission. It was informed about the number of casualties, their conditions, the amount of specialized aid provided by medical organizations, the radiation level in the area around Chernobyl, at the plant itself, and on the contaminated territories, about preventive and sanitary-hygienic measures. Thus, the Commission was at the head of all medical and sanitary work in the afflicted area.

The Commission worked in two main directions: to provide emergency and adequate medical aid to casualties suffering from heat burns and radiation injuries, and to monitor large-scale versatile measures to prevent radiation exposure and its consequences.

Operation groups of the Government Medical Commission were established to elaborate and pass decisions. These decisions envisage:

- the urgent measures to provide first medical aid for the victims of the accident and preventive measures for the personnel of the plant and rescue teams;

- medical aid and preventive measures for the population at the accident site, i.e. in a 30 kilometer zone;

- mobilization of extra forces and means to provide the necessary medical aid, sanitary-epidemiological and preventive measures for the evacuated population, as well as for the population effected by radioactive fallout;

- the participations of the experts from scientific research and medical centers of our country in providing aid for the afflicted areas and elaboration of sanitary-hygiene, antiepidemic measures, norms, criteria and rules of radiation protection.

The Coordination Scheme of the Government Medical Commission (GMC) and other boards and establishments is given in Fig. I.

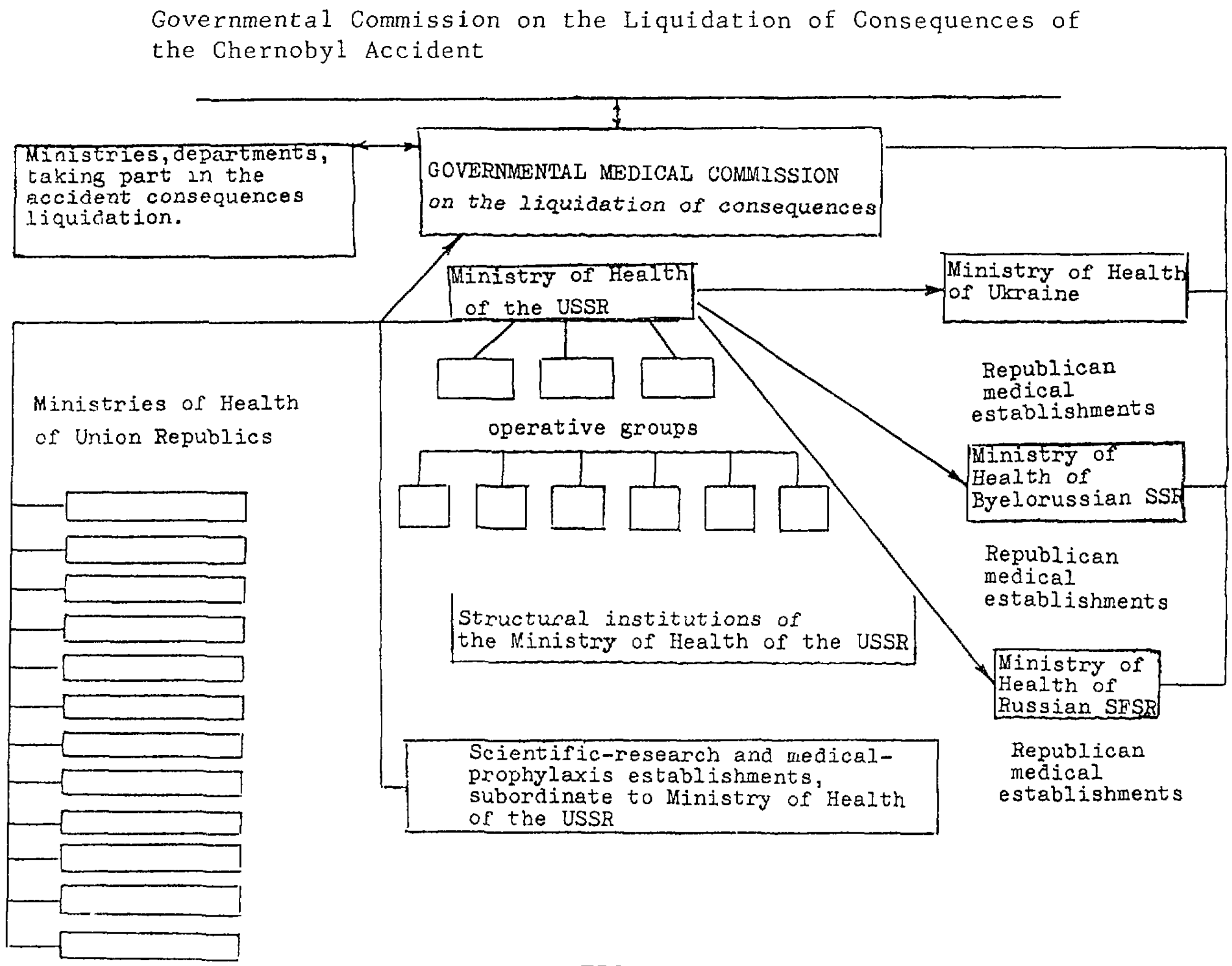


FIG.I.

As we can see in the scheme, the Government Medical Commission coordinated the activities of the Health Ministries of Union republics and medical organizations, being at the head of all medical measures to provide aid in the aflicted areas and ensured cooperation with other ministries and state boards which carried out their tasks in the contaminated areas.

Various decisions of different significance and meaning were not taken only on the basis of the received information. Its members visited the site to study the situation, to give consultative and practical aid, to take part in the consideration and solution of the problems together with the leaders of regional party, Soviet and economic boards, However, we have to admit that the first stage of its activities the solution of the problems was not always effective and operative, what in a number of cases led to contradictory opinions and dragged out the solution of some problems.

One of the first objectives was to estimate the possibility of the population to live in the most contaminated areas.

In an unprecedented short period of time, taking into consideration the growing level of radioactive contamination and on the basis of Safety Standards established in 1976 (SRS-76), it was decided on the criteria for the introduction of emergency measures to protect the public. According to the Government Commission decision over 100 000 people were evacuated from the accident site. Further events proved the importance of this measure as well as iodine prophylaxis. It was necessary to solve many urgent complex problems. It should be pointed out that medical personnel at the plant was informed about the accident 15 minutes after the accident had occured. First medical aid was given both by medical personnel at the local surgery and first aid teams which arrived in 30-40 minutes. First of all, the casualties were taken out of the radiation and destruction zone, then they were sanitized and were given symptomatic treatment. Those with axonal reaction were immediately evacuated. During the first 12 hours 132 people were taken to the hospital. Such serious situation demanded urgent involvement of medical experts of high qualification. The Moscow team of highly-qualified experts began its work in 12 hours after the accident. They examined and gave aid to 350 casualties on 26 and 27 April. Casualties were sent for inpatient examination and treatment in specially prepared clinics in Kiev and Moscow. The total number of 499 people were hospitalized with the diagnosis of "acute radiation sickness".

All casualties got full clinical and radiation examination in dynamics, cellular composition of bone marrow was defined. All these enabled constant and objective estimation of the state of the sick and to provide necessary adequate treatment.

At first, on the basis of clinical examination the diagnosis of acute radiation sickness was confirmed for 237 people. However, subsequent examinations, the analysis of dose burdens according to the chromosome aberration rate and the estimation of clinical symptoms enabled to exclude 92 people from this list.

Clinicians used the modern arsenal of home and foreign-made medicines.

Foreign scientists took part in treating the patients, helped us by sending equipment and medicines, sharing their experience and knowledge in the field of radiation injury treatment (Hammer, Gale, Champlin, Tarasaky and others).

We failed to save 28 people, who were mostly plant workers and fire fighters at the accident scene. I6 people from the total number of casualties do not work yet. This testifies to the fact that the methods and principles of treatment, elaborated by Soviet medicine, turned to be rather effective.

Since the first days of the Chernobyl accident the whole net of the Ukrainian, Byelorussian SSR and several regions of the Russian Federation worked for medical aid in the most contaminated areas. There were engaged 2000 health teames, a considerable number of scientists from scientific-research institutes, as well as engineers and technicians for dosimetry investigations (see Table I).

The objective of medicine was to introduce public health radiation observation. All evacuees from the accident zone were subjected to thorough examination and dosimetric tests in order to define their state of health, possible radioactive contamination of personal belonging and skin. The content of incorporated radioactive isotopes was defined. High-sensitive body monitors

Table I. The number of specialists involved in medical aid and examination of the evacuees and the population of the regions contaminated by radiation fallout

The organization	Health teams	Doctors	Low-grade medical workers	Students	Scientists and engineers
Ukrainian SSR	297	2000	4000	I250	-
Byelorussian SSR	I49	2500	4500	-	-
Russian Federation	I5I8	I9I3	3695	-	938
The system of the USSR Ministry of Public Health		5I9	504	-	686
Total	I964	6932	I2699	I250	I924

(BM) were used for this purpose in June I986. The USSR Ministry of Public Health approved the establishment of specialized hospitals in Kiev, Minsk and Moscow. Their main objectives were to find out, register and observe in dynamics all exposed individuals as a result of the Chernobyl accident, as well as their treatment and public consultations. The All-Union Scientific Centre of Radiation Medicine of the USSR Academy of Medical Sciences was established to ensure profound scientific investigations of the outcomes of the accident, coordinate all measures and observe different contingents of the population.

More than 600 thousand people (including 2I5,3 th.children) were thoroughly examined. 37,5 th. people (including I2,6 th. children) underwent examination at the hospitals as prophylactics, obtaining more accurate diagnosis of various diseases or because of their personal initiative. There were no deviations of the state of health connected with the exposure. This was the result of large-scale prophylaxis measures, which proved to be rather effective.

They were carried out by health services in coordination with other departments. First of all, these were sanitary-hygiene measures aimed at radiation safety and maximum decrease of outer and inner public exposure in the vicinity of the Chernobyl Nuclear Power Plant, as well as in some regions of the Ukrainian SSR, Beylorussian SSR and Russian Federation and the personnel at the accident scene.

In the period of radioactive release sanitary-hygiene services together with meteorological services conducted monitoring of radioactive fallout. It enabled to determine the regions with high level of radiation. Effective control of radiation, radiation-hygiene services, monitoring foodstuffs and drinking water were introduced in the aflicted areas. On 3 May 1986 the USSR Ministry of Public Health approved "Temporary Standards of Permissible Content of ^{131}I in drinking water and main foodstuffs".

Taking into account the annual consumption of different foodstuffs, the technology of their production, there were introduced temporary regulations governing the radionuclide content in all foodstuffs, fruits and vegetables, herbs and several medicines.

In accordance with the guidelines the sanitary and epidemiological services, the USSR State Commission for the Agricultural Industry solved the problems of food supply.

All these measures led to the substantial reduction of the intake of radionuclides with foodstuffs and public exposure.

Tough measures were introduced to control the possible ways of radiation transfer from the zone of the Chernobyl Nuclear Power Station and from the territories with relatively high level of radioactivity. The Ministry of Public Health in coordination with the Ministry of Home Affairs, the Ministry of Railways and the Ministry of Civil Aviation established the net of dosimetric control posts. These posts carried out dosimetric control of the transportation means (including air and railway transport), vehicles, footwear, dress according to the permissible levels approved by the Ministry of Public Health.

Medical personnel supervised decontamination of settlements, roads, different buildings, premises and means of transport, and it should be pointed out that it was rather tough and effective.

In addition to the measures, aimed at radiation safety of the regions near the plant, a special attention was given to better sanitary and epidemiological conditions.

The problems of psycho-emotional tension and radiophobia were also in the focus of our attention. They can be explained by the lack of immediate, adequate and commonly understood information about real radiological situation. Medical personnel was not always very well trained in these problems.

Erroneous understanding of real radiological situation and alleged exceptionally hazardous influence of all radiation doses was shaped by traditional information about the consequences of nuclear energy use for military purposes. At the same time the public had superficial knowledge of the fact, that not only the appearance of life, but the evolution of biosphere was accompanied by ionizing radiation.

Therefore, the level of explanatory work and sanitary education had to be increased. And it is possible to mention, that it enabled considerable reduction of psycoemotional tension and the syndrome of radiophobia. It can be judged from the decrease of a number of letters the USSR Ministry of Public Health receives from the population of the Ukrainian SSR, Byelorussian SSR, Russian Federation and other republics. This work will be conducted in the coming years.

The basic knowledge of constant presence of radiation in the biosphere and its biological influence, methods of its measurements had not been brought to public notice and this is our serious mistake.

A special attention was paid to the health of the children. Their health was thoroughly monitored in that situation. According to the proposed measures of the Ministry of Public Health more than 350 thousand children and pregnant women were sent to sanatoriums, rest homes and pioneer camps in 1986-1987. Prophylactic measures were carried out in schools and kindergartens under rigorous control.

There were sent the necessary medicines, devices and different medical equipment to increase the quality of medical and sanitary service. In addition 1000 people were employed at different organizations of the Ministry of Public Health. Large-scale, purposefull and long-term work gave qualitative and quantative results. Thus, the complex of prophylactic sanitary and hygiene measures enabled to avert the outbreaks of infectious diseases in the places of mass gathering of people, to reduce the radiation dose by 70% compared with the predicted one. What is the real annual external exposure dose? The majority of people have got the dose equal to that which the patients get during plain roentgenography.

The analysis of the state of public health, including pregnant women and children, confirmed the absence of deviations, which might be related with the influence of radiation. The number of diseases and deviations in the state of health is not the same as that in the regions, which were not contaminated. The increase of the number of general diseases in several regions was due to better quality of medical examination and psychoemotional influence.

Since the first days we have solved both the urgent problems of eliminating the medical consequences of the accident and the problems of the long-term program of public observation. The All-Union register of all persons subjected to radiation exposure was established to ensure the long-term dynamic observation of the public state of health. The children and grandchildren of all persons subjected to radiation will be also included in the register.

It also contains information about radiation doses, the evaluation of the state of health, its changes and the cases of providing medical service. The criteria for the All-Union register and dispensary observation of different categories of the population are given in Table 2, the scheme of receiving information by the All-Union register and reverse connection with organizations which provide out-patient observation is shown in Table 3.

Table 2. Criteria for registration in the All-Union register and the levels of all-round observation of exposed persons as a result of the Chernobyl accident

The cathegory of observation	The character of the observed persons	^{131}I thyroid burden during the first year after the accident (in rad)	The level of organizations for all-round observation	The level of register
I	2	3	4	5
I	Persons after radiation sickness, still sick or with radiation injuries, as well as sicknesses which are closely connected with radiation injuries as a result of the accident or the elimination of the consequences of of the accident		They are observed in the clinical hospital N6 of the Ministry of Public Health; ALL-Union Scientific Center of Radiation Medicine and other specialized organizations	The country level of register (special registers at the Institute of Biophysics of the Ministry of Public Health, All-Union Centre of Radiation Medicine of the USSR Academy of Medical Sciences

Table 2 (cont.)

I	2	3	4	5
2	Persons involved at the accident scene, evacuated from the radiation zone and also persons with the doses of radiation:		They are observed in specialized organization of the republic or All-Union Scientific Center of Radiation Medicin of the USSR Academy of Medical Sciences	The country level of register(Scientific Research Institute of Medical Radiology of the Academy of Medical Sciences),republican register
	adults	25 and more		
	pregnant women (at the time of the accident) and their children born after the accident	5 and more		
	new-born children,children, teenagers	5 and more		
3	All other persons involved at the accident scene irrespective of the radiation dose. Evacuees from the radiation zone,as well as other persons with radiation doses:		They are observed at their local clinics of Central republic hospital level (they are given consultations at the specialized clinics in case of necessity)	The country level of register(Scientific Reasearch Institute of Medical Radiology of the Academy of Medical Sciences), republican register
	adults	I0-25		
	pregnant (at the time of the accident) and their children born after the accident	I-5		
	new-born children, children, teenagers	I-5		

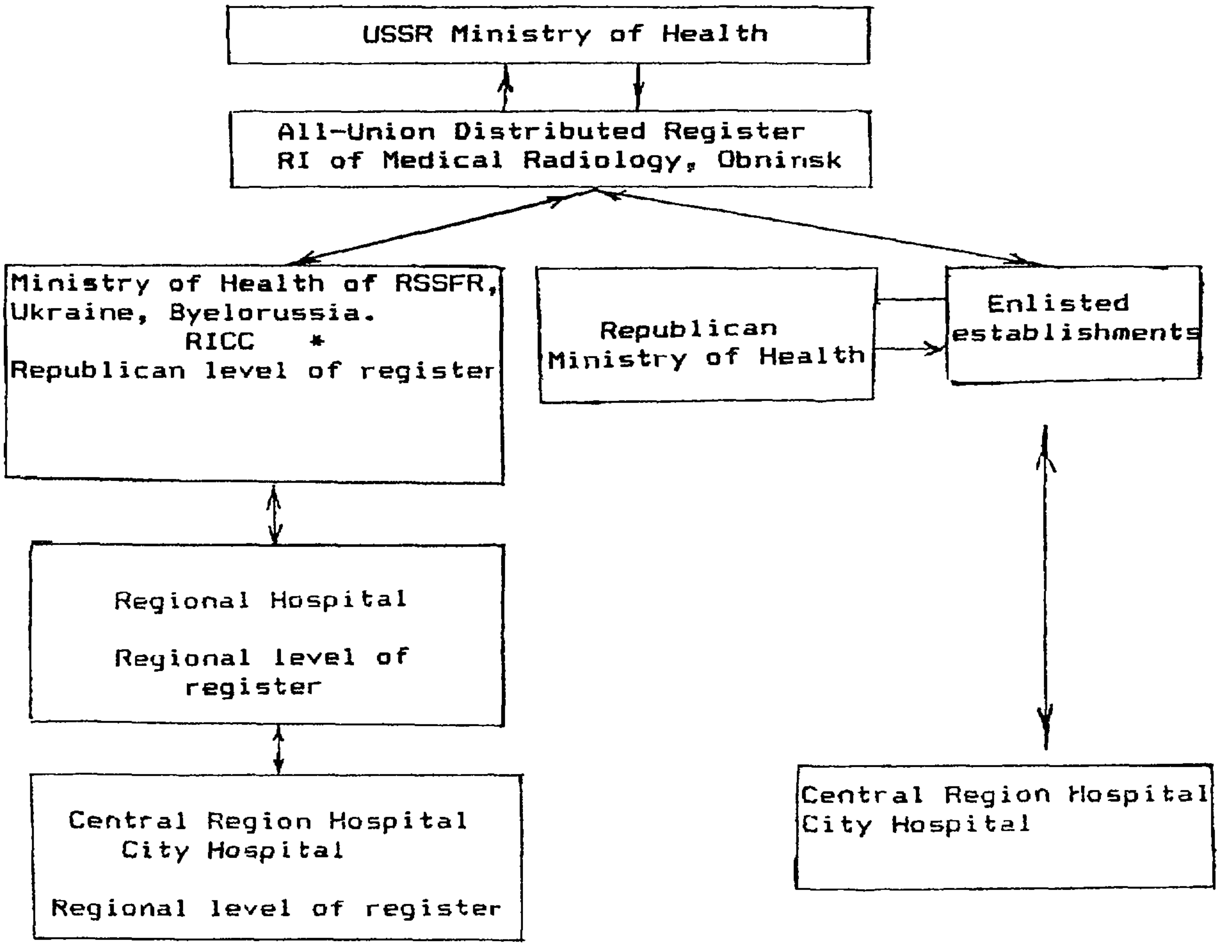
Table 2 (cont.)

I	2	3	4	5
4	All other persons, evacuated from the radiation zone irrespective of the radiation dose. Persons of the controlled region with radiation doses	5-IO	They are observed at their local clinics of Central republic hospital level (they are given consultations at the specialized clinics in case of necessity)	Dynamic observation at the level of the region (regional register), the data are sent to the republican and All-Union levels of register in Scientific Research Institute of Medical Radiology of the Academy of Medical Sciences
	All pregnant and their children born after the accident in the controlled region irrespective of their radiation doses. New-born children, children, teenagers irrespective of their radiation doses in the controlled region. Children born from the father, who received the radiation dose of 25 rad in the period of 3 months before conception			
5	Other persons in the controlled region with radiation dose and children born from parents of 1, 2, 3 groups.		They are observed at their local clinics (they are given consultations in profile hospitals in case of necessity)	Dynamics observation of regional register

Note: evacuees are persons, who were evacuated from the radiation zone, as well as those who left it on their own since 26 April I986; the personnel is observed at the clinics where they work and after work - at the local hospitals where they live.

Table 3

SCHEME OF RECEIVING INFORMATION TO THE ALL-UNION DISTRIBUTED REGISTER AND REVERSE CONNECTION WITH ORGANIZATIONS WHICH PROVIDE OUT-PATIENT OBSERVATION



* Republican Information Computer Centre

It should be stressed that scientific forecast calculated by scientist about the possible consequences of the accident at the Nuclear Power Station for the population of this country and other regions of Europe, which were partially afflicted by radiation fallout, generally coincided with the forecast of WHO and IAEA experts. The predicted increase of oncological and genetic diseases, which can occur as a result of exposure, will not amount to more than a few hundredths of one per cent and cannot practically be distinguished from spontaneously occurring diseases. The radiation doses received as a result of the Chernobyl accident in the following 50 to 70 years will not exceed the dose caused by natural radiation background by more than 20-30%.

However, in order to study the possible consequences of the exposure and to take immediate medical measures long-term "Complex ecological program to investigate the consequences of the Chernobyl accident" was approved. The basic clauses of it are given in Table 4. More than 100 scientific-research establishments participate in this program.

Table 4. The main scientific directions elaborated in the frames of "Complex ecological program to investigate the consequences of the Chernobyl accident"

The study and substantiation of the regularities in the formation of individual and collective absorbed doses as a result of the Chernobyl accident. The development and substantiation of radiation forecast and dose burden.
The study of epidemiological, clinical and functional, genetic and ecological aspects of public health under the influence of radiation resulted from the Chernobyl accident.
The creation of automated system to process the results of public examination in the regions which are close to the Chernobyl Nuclear Power Station. The establishment of All-Union Distributed clinic and dosimetric register of the exposed persons and its operation.
Experimental study of radiation and medical problems caused by the Chernobyl accident.
The development of hygienic measures to protect the public from ionizing radiation.
The generalization of the experience of public health organizations eliminating the consequences of the accident at the Chernobyl Nuclear Power Station.

Mass media constantly covered the state and measures to eliminate the consequences of the accident. In the first days of the accident Soviet experts of the Ministry of Public Health met a number of foreign representatives on their request, answered their questions and gave necessary information about the problems they were interested in.

The General director of the World Health Organization Mr.H.Maler was sent a detailed information about the Chernobyl accident and its medical consequences.

Soviet scientists submitted the calculations of the collective absorbed doses especially for the population in the European part of the country to the IAEA meeting of experts in August I986.

The experience of the Soviet experts in the elimination of accidents was highly estimated abroad. The Soviet expert took part in the liquidation of the consequences of the accident in Brasil, which was reported by the press.

Speaking about the huge amount of work done by the medical staff to secure the public in the face of the accident, it is impossible to pass over in silence some negative features. The relative prosperity in running nuclear plants before the Chernobyl accident played the definite role in the appeared complacency of several leaders of public health and medical organizations. There was no clear scheme of actions of all medical organizations in case of large-scale accident. The medical personnel even in hospitals had not adequate training in the field of radiation pathology. They did not know enough the methods of diagnostics and treatment of radiation injuries, in a number of cases they did not receive information about the necessary methodological literature on these problems, which was kept on the shelves of medical administrators. All this can explain both way flow: the victims had to be taken from Chernobyl to Moscow, and the experts had to go from Moscow and Kiev to Chernobyl.

Radiological service had not enough of dosimetrical and radiometrical devices in reserve; and in number of cases there were simply no necessary devices. A lot of them, which were available in the arsenal of radiological equipment were out-of-date.

Regardless of the existing planned training of experts to provide radiation control, additional courses of radiation measurement methods for medical personnel had to be organized since the first days of the accident.

The elimination of these drawbacks in the course of the accident led to the loss of time and demanded more efforts and expenditures. Till the present time the Ministry of Public Health has done and continues its work in creating the conditions for the optium functioning of the public radiation security system.

The measures taken at the Chernobyl Nuclear Power Station were constantly within eyeshot of the Government commission, Central Committee of the CPSU and the Council of Ministers of the USSR.

The succesful work of medical personnel would have been impossible without constant help received from the local party, Soviet and economic organizations.

In conclusion, it should be mentioned that all sorts of conjectures about negative influence of the consequences of the Chernobyl accident on the public health should be disproved by real data. We have no reasons to hide them. The participants of the conference - scientists and experts have an opportunity to study all materials and express their views on all aspects of the Chernobyl accident.

SANITARY AND HEALTH MEASURES TAKEN TO DEAL WITH THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT

A.I. KONDRUSEV

Abstract

By the end of the first year after the accident, more than 20 million gamma background measurements had been made at population centres; 500 000 samples of drinking water and water from open reservoirs, and 30 million different surfaces (transport vehicles, housing, ground, clothing, etc.), had been tested. Analyses had been made of 700 000 samples of milk and milk products, 120 000 samples of meat and meat products and more than a million samples of other food products.

Iodine prophylaxis was administered to 5 400 000 people, including 1 690 000 children.

Temporary whole-body exposure limits of 100 mSv (50 mSv for external exposure and 50 mSv for internal exposure) were introduced for the first year after the accident, in the light of scientific data on the effects of various exposure doses and in view of the actual radiation conditions. The standard for 1987-88 was reduced to 3 rem (30 millisievert), in view of the actual reduction in exposure levels achieved as a result of the large-scale clean-up measures undertaken.

Accident at the Chernobyl nuclear power plant was a serious examination for the physicians of our country.

Hygiene as a branch of science and the practice of sanitary control have accumulated a good experience in prophilaxis of hazardous radiation effect on the population as well as in radiation protection, including the control of construction and operation of nuclear engineering enterprises. The schedule for safe operation of nuclear facilities used in medicine, technology and research is developed and put into operation.

The existing system of sanitary legislative and regulating documents has formed the order of necessary measures on population, including radiation protection at nuclear plant and other nuclear fuel cycle facilities. In I97I the USSR Ministry of Public Health has adopted " Criteria for decision making about population protection in case of a nuclear reactor accident", worked out by the National Committee on radiation protection.

This document determined the necessity of different measures including evacuation from the area neighbouring the accidental site, depending on the actual radiological situation. These Criteria were the basis of sanitary and epidemiological works after the Chernobyl accident.

However, the unique character of the accident, its scale, have urged the USSR Ministry of Public Health and its sanitary-epidemiological services to organize and conduct complex coordinated measures aimed at the prevention of population overdosage. These measures included:

- development, introduction and organization of strict control of temporarily permissible levels of external and internal irradiation as well as of content of radionuclides in drinking water and food-stuffs, permissible density of radiocontamination of ecosystems, houses, transport, different things used every day, and skin:
- organization of mass iodine prophylaxis;
- introduction of severe regulations in behaviour of people on the territories were the doses enhancing established limits could form;
- organization of the system of training courses for the population for the increase of the knowledge on radiation hygiene.

The special role in the whole system of sanitary-epidemiological facilities was that of coordination of activities of various ministries and departments, which aimed at the realization of the above-mentioned measures.

Measures on prophylaxis and sanitary-epidemiological control were put into action in the first hours after the accident, for instance, iodine prophylaxis for the NPP personnel. In 12 hours iodine prophylaxis involved the whole population of the town of Prip`at. Later the scale of iodine prophylaxis has widened according to the actual situation, the complicated character of radionuclide deposition and the duration of radionuclide release into the environment. Totally iodine prophylaxis involved about 5 400 000 persons including I 690 000 children. Already on the 30 April 1986 the decision was made about the exclusion from the ration of milk from the cows kept in property on contaminated territories.

For the protection of people involved in the clear-up process, the Ministry of Public Health introduced a derived limit of 250 mSv, i.e. a level which does not exceed that recommended by the ICRP and existing in Radiation Safety Standards-76 for people involved in emergency work. This level was subsequently reduced to 100 mSv per year and to 50 mSv per year in the third year for particularly dangerous work. Strict radiological control is established to ensure the standards are observed.

Since the first days after the accident vast sanitary-hygienic measures were undertaken, they were aimed at the ensuring of radiation safety for the population of the areas, neighbouring the Chernobyl NPP as well as the reduction of external and internal irradiation of the population of Ukraine, Byelorussia, Russia and other republics.

The establishments of sanitary-epidemiologic service had organized permanent intensive control of radiological situation on the territories with the enhanced radioactive contamination. Under control were also food products and drinking water. This work was conducted together with the State Department of Hydrometereology, State Department of Agriculture, other Ministries and Departments.

On the basis of scientific data on the effects of various irradiation doses and actual radiological situation temporary dose limits for the population were introduced: I00 mSv (50 mSv for external and 50 mSv for internal irradiation). Taking into account real decrease of irradiation levels as a result of complex measures, radiation standards for 1987-1988 were reduced up to 50 mSv.

These levels as well as the fact that during the first post-accidental year the determining factor of internal irradiation were iodine isotopes (first of all I-131 due to its uptake with drinking water, milk amd some other food stuffs) on the 3 May 1986 the USSR Ministry of Public Health has introduced " Temporary dose limits of iodine concentration in drinking water and food products".

Later, taking into account the annual uptake of various food stuffs, their production technology as well as cummulative peculiarities of long-living radioisotopes, on 30 May 1986 were adopted temporary permissible levels for the whole nomenclature of food products, medical preparations and drugs.

For the provision of the system of radionuclide control in food products, the USSR Ministry of Public Health together with the USSR Ministry of Agriculture has worked out and put into operation the standards on treatment, processing and preparation for realization of products of cattle-breeding, fowling forage, forestry on contaminated territories.

Moreover, The USSR Ministry of Agriculture on accordance with the USSR Ministry of Health has formed the peculiarities of agriculture on the territories with enhanced radioactive background.

Enterprises of sanitary-epidemiologic service and controlling organizations of the USSR Ministry of Agriculture followed the directions of the mentioned documents at making decisions connected with the realization of food products through state shops, public catering, markets.

The basis of this system of radiological control was the uniform method of immediate determination of volume and specific activity of beta-emmiters in water, food stuffs, plants and soil by " direct " measurement of "thick" samples.

Due to the complicated radiological situation, significant fluctuations of radionuclide content in food stuffs produced on contaminated territories as well as due to the necessity of precision measurements, regulations were adopted, according to which the results of radiological control conducted by departmental services and organizations were not considered the basis for making decisions connected with the realization of food products. These decisions were made only on the basis of data obtained by sanitary-epidemiological establishments and control services of the USSR Ministry of Agriculture.

All the mentioned measures allowed to decrease significantly the radionuclide uptake with food stuffs and ensure the maintenance of the established level of internal irradiation.

Reliable covering force was put on the way of anthropogenic transfer of radioactive substances from the NPP-site and highly contaminated areas. Strick control of radioactive contamination of transport, technique, footwear, clothes, linen etc. had been organized on dosimetry stations and sanitary posts according to the established by th USSR Ministry of Public Health temporary permissible (control) dose limits. (That was already mentioned by G.U. Sergeev in his report).

Enterprises of sanitary-epidemiologic service, research institutions of the USSR Ministry of Public Health together with the organizations of the USSR State Committee on Hydrometeorology and USSR State Atomic Energy Control had performed systematic control of radioactive contamination of air and soil. For radiometry and dosimetry 1000 posts and laboratories were formed, 3 500 specialists enlisted for these works, over 3 250 dosimetric and radiometric instruments involved as well as 16 mobile laboratories. The scale of works carried out by sanitary-epidemiologic service on the accident impact mitigation was really large: by the end of the first afteraccidental year more than 200 000 000 gamma-background checks were performed in populated areas, as well as 500 000 examinations of drinking water and water from open aquatic basins, 30 000 000 measurements of surface samples (transport, apartments, territories, clothes etc.). Measurements of more than 700 000 samples of milk and milk products, 120 000 - of meat and products, over 1 000 000 - of different food stuffs were done.

To provide sanitary-hygienic safety of the population additional efforts of sanitary-epidemiologic stations, situated on contaminated territories were desired. Thus, 8 interregional radiological departments, 7 radiological groups, 13 groups of individual dosimetry were additionally organized. In Br'ansk region (Russian Federation) research laboratory of radiation hygiene was opened. At 15 sanitary-epidemiological stations the staff of radiological departments was incresed.

Much attention was also paid to the training of specialists in radiometry and spectrometry. For different ministries and departments over 1 000 specialists were prepared on the basis of sanitary-epidemiological service. That gave the opportunity to enhance the identification of radionuclides and control of their contents in agricultural products on all the stages of their production, laying-in and processing as well as in environmental samples.

At the same time at critical areas was introduced the enchanced control of sanitary-epidemiologic condition of the most important objects, first of all food industry, public catering, trade, water supply of populated territories. Individuals ignoring sanitary-hygienic regulations were subjected to severe measures specified in statute of State Sanitary Control in the USSR. Thus, for the violation of sanitary-hygienic and anti-epidemiologic regimen, during 1986-1987 over 23 000 officials were fined, more than 5 500 were removed from business, 2 643 different objects stopped operating, administrative actions were brought against more than 2 000 persons.

Due to anxiety prevailing in the mood of population, that expressed in inadequate estimation of the situation and fear of irradiation consequences, local public health organizations as well as radiological specialists working at-site had carried out a huge sanitary-elusidative work aimed at the reduction and prevention of psychological tention and radiophobia, introduction of primary knowledge of personal protection and peculiarities of life on contaminated territories. Only in 1986 mobile agitatingteams gave 119 guest performances, 1 400 lectures were delivered as well as 1 500 debated, 91 question-and-answer parties, 115 articles appeared in local papers, 62 radio and TV broadcasts, 92 documents on medical aspects of radiation protection were published. This work is being continued.

When speaking about the large work conducted by sanitary-epidemiologic service we should mention certain shortcommings that have revealed during this period. Not every sanitary-epidemiologic enterprise was ready in the whole volume for the work in the conditions of a large-scale radiation accident. Normative documents regulating control of food stuffs were as a rule directed ar the monitoring of background content of radioactive substances, Radiological services had no sufficient reserve of dosimetric and radiometric instruments. During the initial period there was no strict coordination of activity in different links of sanitary-epidemiological service.

THE CHERNOBYL EXPERIENCE IN THE CONTEXT OF CONTEMPORARY RADIATION PROTECTION PROBLEMS

L.A. IL'IN

Abstract

Mean individual exposure doses to critical population groups living in the regions under strict control did not exceed the established temporary dose limits for the first and second years after the accident (100 and 30 mSv respectively). The external gamma exposure doses to those living in the contaminated areas did not exceed 50 and 15 mSv, respectively, for 97% of the inhabitants. Internal exposure doses due to incorporated radioactive caesium nuclides did not exceed 50 mSv for the first year and 20 mSv for the second year after the accident for 99% of the population; and for approximately 90% of those living in the regions under control, these doses did not exceed 10 mSv for both the first and second year.

It was virtually guaranteed that the doses received by the majority of the population in the regions under control were less than half the temporary dose limits for the first and second years after the accident (for about 95% of the population in the first year and 90% in the second year).

Concentrations of radioactive caesium in the bodies of those living in the regions under control were on average 2-5 times lower in the summer of 1987 than in the summer of 1986, and in some cases the difference was measured by factors of 7-10.

The implementation of the whole complex of measures brought about a 5 to 20-fold decrease in the thyroid dose commitment for children, a 1.3 to 2.5-fold decrease in the external gamma dose (depending on occupation and age) and a 10-fold or greater decrease in internal exposure doses.

Experience of large-scale work in the management of the accident at Unit 4 of the Chernobyl nuclear power plant is still being thoroughly analysed and generalized.

Among numerous aspects, of particular interest and significance is further improvement of the radiation protection system with regard to a major accident.

The present report is intended to discuss a number of problems in this field stemmed from the Chernobyl events. This attempt is based on my personal experience gained in the handling of the accident, especially at an early stage, and in scientific guidance of the biomedical aspect of the problem.

TABLE 1. Scheme of development of a large-scale NPP accident, the most adequate countermeasures

Accident phases (according to the WHO terminology)	Accident stages	Exposure sources	Main types of exposure	Protective measures and their applicability
Early	I (up to 24 hours)	Radioactive cloud, precipitation on body	External (total), internal (inhalation)	Timely notification(+), protection of respiratory organs(+) and body (+), iodine prophylaxis(+), evacuation(+-), individual decontamination(+)
	II (2-7 days)	Radioactive cloud, precipitation on body, on soil, food chain *	External (total), internal (inhalation, digestive tract) external and internal (adsorption)	Sheltering(+-), protection of respiratory organs and body(+), iodine prophylaxis (+-), evacuation(+), individual decontamination(+), limiting of access into controlled areas(+), food stuffs and water control(+)
	III (2-6 weeks)	Precipitation on soil, food chain	External, internal (through digestive tract)	Migration(+-), food stuffs control(+), territory decontamination(+-), access limitation(+-)
Intermediate	IV (1,5 - 2 months after the accident	Precipitation on soil, food chain	External, internal (through digestive tract)	Food stuffs control(+), territory decontamination(+-)

NOTE. * - depends on the season, when the accident takes place; (+) - applicable and even necessary; (+-) - applicable, but require cost benefit analysis.

It should be stressed, above all, that a great number of large-scale measures aimed at localizing the accident and eliminating its consequences were planned and implemented on the basis of the system (previously developed in the Soviet Union) of radiological protection in the case of a nuclear reactor accident. An important link of this system is represented by the radiological criteria for decision making on measures to protect the population in the event of a reactor accident as developed by my colleagues and me in the 1960s (see Table 1 /1/).

According to these criteria (A and B), the emergency protective measures are all determined by the limits of predicted external gamma doses and thyroid doses for children. For level A, doses are 0.25 Gy and 0.25-0.30 Gy; for level B, they amount to 0.75 Gy and 2.5 Gy, respectively. Unless level A is exceeded, the protective measures do not involve the disruption of the public living routine.

If radiation exposure exceeds level A but does not reach level B, decisions (including evacuation) should be made on the basis of the actual situation. If level B is predicted to be reached, emergency measures, evacuation of the population from the exposure zone above all, are absolutely necessary. At an early stage of the accident, our general task was to avoid public exposure within the A-B range and, in any case, to prevent whole-body gamma exposure for the population outside the evacuation zone from exceeding a level of 100 mSv over the first year after the accident. The decision to evacuate the population of the town of Pripyat was not taken when public exposure had reached or exceeded level A, but rather at the point when the radiation situation predictions indicated such probabilities /2/. In practice, as a result of the evacuation of the population from Pripyat (45 000 people) and from a 30-km zone round the plant, individual whole-body doses for most of the town's inhabitants were about 15-50 mGy, and for part of the citizens (doctors, militiamen, municipal workers, i.e. those who spent long periods of time outdoors), the average individual gamma dose amounted to 130$\pm$30 mGy. It was in very few population centres of the 30-km evacuation zone that, due to continuous variations in the radiation conditions, not all the inhabitants could be prevented from receiving doses over level A, but these did not reach level B. Because of a timely iodine prophylaxis, the thyroid dose for 97% of the children from Pripyat was below 0.3 Gy, for 2% it was 0.3-1 Gy, and for less than 1% it amounted to 1.1-1.3 Gy. In the management of the accident, an emergency standard for whole-body exposure of 0.25 Sv was immediately introduced in the 30-km zone.

Wide-scale medical examinations covering about one million people revealed no case of acute radiation sickness among the population examined. Except for those damaged within the plant site during the accident (237 persons with diagnosed acute radiation sickness), no case of radiation sickness was established in the participants of the accident-management operation.

Thus, experience of radiation protection of the public and those dealing with consequences of the accident within the 30-km zone at an early stage and, the more so, in the subsequent period indicates the determining part of pre-set exposure regulations as guidance for those responsible for decision making under complicated and difficult circumstances. In addition, of no less importance is an effective system of strict control of the observance of these regulations. It was due to meeting the latter requirement that possible human overexposures were essentially prevented.

The Chernobyl accident posed a number of most difficult problems, so that decision making relative to radiation protection required not only a high organizational effectiveness but also hot recommendations. The main reason was due to extraordinary characteristics of the Unit 4 reactor accident. These are known to be associated with two events: explosive break of the core containment, the graphite burning, and, as a result, a 10-day release of gases and aerosols containing great amounts of radioactive material into the environment/3/.

The above factors together with sharp variations in the meteorological conditions in the accident area led to a considerable contamination of some regions.

Under the circumstances, the general assessment of the radiological conditions, the organization and, if necessary, realization of measures on radiological protection of the population and environment were all based on the results of an unprecedented wide-scale health and environmental monitoring.Immediately drawn into these activities were thousands of scientists, specialists of different civil offices and of the Ministry of Defense, as well as local subdivisions of the State Committee on Hydrometeorology, radiological teams of sanitary and epidemiological stations under the Ministries of Health of the Soviet republics, radiological service of the veterinary and agricultural supervision, etc. In a short time, millions of radiometric and dose measurements were carried out and then analysed and generalized by local organizations, regional centres, and the sceintific staff of the State Commission.

In this enormous work, though effectively performed as a whole, many problems and questions arose, among which, in terms of further improvement of radiation monitoring, the following should be noted.

First. All dosimetric and radiometric facilities available were used.

From experience follows the necessity of their further unification, strict regulations on possible usage, redetermination of sensitivity thresholds and limits in reference to emergency, adequate indications of the instruments taking into account the nature and specific features of radiation registered, as well as simple usage and compactness.

Of significance is the unification of the scales of these instruments according to the accepted system of units.

Of particular importance are specific developmental efforts to improve methods of back-determination of absorbed doses to the human body following external and internal exposure. We have once again seen that the methods of "dosimetry without dosimeters" are very promising for the reconstruction of absorbed doses from external exposure (e.g. by ESR or RLL signals in different materials, including samples of hair, nails, tooth enamel, clothes). Thus, determined at our Institute by ESR signals from enamel, doses to three persons died from radiation sickness proved to correlate closely with the severity of damage. The Chernobyl accident demonstrated the importance of assessing doses to open parts of the human skin. For instance, the results obtained with the help of multilayer thermoluminescence dosimeters developed at our Institute /4/ for measuring absorbed doses of beta and low-energy gamma radiation to the skin show that such dosimeters should be included into the emergency system of personal monitoring.

Second. Taking into account actual radiation hygienic conditions, the scope and frequency of control may be essentially changed. For example, ^{131}I is known to be the dominant and most "characteristic" radionuclide in environmental objects and foodstuffs within the first days and weeks after the accident. In a short time, methods of ^{131}I measurement in environmental samples were detailed for cases when gamma-spectrometric measurements were impossible (because of an enormous number of samples and for lack of gamma-spectrometers at farms and in other places where tentative conclusions about, say, milk activity were necessary). Methodological problems of mass thyroid gamma-exposure rate measurements had been solved for those cases when portable gamma radiometers were used. Models for the calculation of individual thyroid doses from radioiodine inhalation, allowing for different living conditions in contaminated areas and patterns of dairy products consumption were developed, including necessary tabulated data and numerical values of formula parameters.

The Chernobyl accident therefore necessitated organizing and carrying out a great number of various measurements of activity in environmental objects and object samples, the human body included. In particular, lifetime ^{131}I, ^{134}Cs, and ^{137}Cs contents were measured in more than 600 000 persons. The vast mass of data, with allowance for methods of estimation, made it possible to classify the population by exposure levels and, on this basis, to take sanitary and hygienic, medical and organizational measures necessary for normalizing the situation and mitigating the radiological impact.

The main conclusion from this experience is that the whole system of adequate radiation and radiometric monitoring and the scope of control under conditions of a major accident should be further improved.

It is known that, before the Chernobyl accident, in the USSR as well as in other countries only annual limits on intake of radionuclides with food were set. The concentration of nuclides in drinking water was also regulated (see Standards of Radiation Protection 76 /SRP-76/). Radionuclide contents of individual foodstuffs were not standardized. At the same time, a standard on ^{131}I was specified in case of an accident (so that the thyroid dose for children should not exceed 300 mSv). This requirement was met with a milk concentration of 3700 Bq/l.

After the Chernobyl accident, there arose a necessity for immediate settling the problems connected with the assessment of foodstuff activity and sorting or prohibiting certain kinds of food. Accordingly, standards were calculated and introduced immediately for ^{131}I contents of 24 foodstuffs and medicinal raw materials, including dairy products (curds, sour cream, cheese, butter), leafy vegetables, meat, poultry, eggs, berries, with allowance for their contribution to the diet.

Subsequently, late in May 1986, standards on ^{134}Cs and ^{137}Cs content of meat, milk, and some other foods were introduced because of their increased relative contribution to contamination of these products. These standards were calculated for permissible dose of 50 mSv for exposure of the whole body and internal organs over the first year after the accident.

Temporary permissible levels of surface contamination (for premises, transport, equipment, clothes, shoes, personal protective means, and skin) were calculated and approved to prevent additional internal and external exposure of people and human-caused escape of radioactive materials from the 30-km zone. Moreover, corrected permissible levels of contamination were adopted for the ground surface, outer and inner building surfaces after decontamination. To improve control of agricultural produce activity, 28 standards were formulated which regulated the order of treatment, processing, and preparing for realization of various livestock, poultry, fodder, fur products, etc.

The most complicated regulation problems primarily dealt with organizing the radiation monitoring of roads, buildings, transport, house-hold articles, etc. To carry out such large-scale operations, safe but realistic, under the circumstances, standards were needed. Standards set in early May 1986 were repeatedly reviewed in terms of making them more strict and approaching the SRP-76 values, as the radiation situation was returning to normal. In particular, after the decontamination of Units 1 and 2 and the construction of the "Ukrytie" object (Unit 4 tomb) had been essentially done, we turned back to setting standards for contamination of unit premises at SRP-76 levels for beta-particles. At the 30 km zone boundary, the SRP-76 standards for skin of workers were set as permissible levels of clothes contamination. On the whole, experience of standardization and organization of radiation monitoring showed that, even in the eventof such a major accident, science-based measures allowed to prevent radioactive material from spreading over the 30-km zone boundaries and considerably decrease the danger of contamination of people, their belongings and dwellings by a massive and highly laborious decontamination operation. This, along with other practical, sanitary and hygienic actions, permitted a sharp reduction of adverse effects of the accident. One of the most important problems was to set a temporary dose limit for the public in areas with high exposure levels.

According to the Sanitary Rules of Nuclear Power Plant Designing (SRNPP-79), such a limit of public exposure in the case of a design-basis accident was represented by an individual dose limit of 100 mSv, used as a temporary one for the first year after the accident. Later on, the NCRP introduced a more strict standard of 30 mSV for the second year after the accident. These regulations formed the basis for effective implementation of the whole tremendous complex of accident - management actions.

An analysis of actual data, with allowance for all protective and preventive measures, suggests the following.

Average individual doses for the critical population groups in the regions under strict control did not exceed the dose limits for the first and second years after the accident (100 and 30 mSv,respectively). External gamma doses did not exceed 50 and 15 mSv, respectively, for 97% of the population permanently living in contaminated areas.

Internal doses from incorporated radiocaesium did not exceed 50 mSv over the first year and 20 mSv over the second year after the accident for more than 99% of the population, and in approximately 90% of inhabitants of the regions under control they did not exceed 10 mSv either for the first or second year after the accident.

In other words, due to the above efforts, doses to the majority of the population in the regions under control proved to be less than half as high as the temporary dose limits in the first and second years after the accident (for about 95% of the population in the first year and for 90% in the second year).

In those regions, the radiocaesium content of the body in summer 1987 was 2-5 times lower and in some persons 7-10 times lower than in summer 1986.

Finally, in 1987 the contribution of internal exposure to the total dose more clearly tended to decrease and did not exceed 20-30%.

On the whole, the measures taken permitted a 5-20 fold reduction of expected thyroid doses to children, a 1.3-2.5 fold decrease of external gamma doses (depending on age and occupation), and a 10 fold and more decrease of internal doses.

These measures include essentially:

1. Evacuation of the population from a 30-km zone, including the town of Pripyat.

2. Formation of a 30-km circular zone around the plant site with hard restrictions and radiation monitoring to prevent an anthropogenic transfer of activity from the contaminated zone to "clean" areas.

3. Prophylactic use of stable iodine by those dealing with sequences of the accident, by the population of Pripyat and of regions bordering upon the 30-km zone.

4. Ban on whole milk consumption, restrictions on dairy cattle grazing or shift to uncontaminated pastures or fodder, foodstuff control sorting, processing, and utilization.

5. Deactivation work in population centres and in the territory adjacent to the Chernobyl plant.

6. Sending the children and pregnant women from the population centres to health resorts in the summer period 1986-1987.

7. A package of measures to substitute, in some areas, local food by food brought from elsewhere.

8. Agrotechnical and ameliorative measures on agricultural land.

As already noted, these measures together permitted a significant reduction of doses to the population (both from external and internal exposures).

Thus, experience of regulating reference levels of environmental contamination and dose limits for the participants of an accident-management operation and for the population of affected areas showed an exclusive role of this component of radiation protection in determining a strategy for accident handling and for providing a reasonably achievable decrease in exposure for different human cohorts.

In addition, experience of the above and other measures clearly demonstrates that, with contaminated areas of throusands of square kilometres, external gamma exposure is a very difficult problem to deal with, especially after relative stabilization of radiation conditions. Unlike more "controllable" internal exposure, as indicated by the above estimates, methods of external gamma exposure handling primarily depend on the decontamination of the human environment. Population centres, forests, fields, and farms, in contrast to the plant site and bordering areas, can be decontaminated only by mechanical removal of radionuclides, without any special solutions concerning active chemical components.

Among the complex and onerous decontamination work, the most difficult was the radiological protection of forests.

Nevertheless, deactivation work taking into account particular features of the various areas is continuing. It should be emphasized that further reduction in gamma ray dose rates in the area will be determined by vertical migration of radionuclides in the soil including the use where possible of deep ploughing and other measures.

From the point of view of reducing the gamma ray dose rate, soil decontamination due to transfer of radionuclides (^{137}Cs included) to the overground parts of plants should be considered as insignificant.

The problem of the assessment of the possible radiological impact of the accident on the USSR population has been already discussed /2, 7/. The collective dose commitment for the entire population of the country is estimated to be about 326 000 man-Sv, based on an analysis of field material, with allowance for effectiveness of the measures taken and those being carried out. According to the dose-response relationship without threshold and the ICRP risk factors for stochastic effects /8/, cancer death excess may be expected to constitute hundredths of per cent of spontaneous values, the corresponding number of genetic defects in the progeny of the first two generations of exposed parents being hundredths of thousandths of per cent. Our data show a satisfactory correlation with more recent frequency estimates of expected late radiological effects of the Chernobyl accident on the population of Western Europe /9/ and Northern Hemisphere /10/.

The basic data for calculations made in the USSR are presented in a series of figures. It should be stressed that an analysis of actual and calculated data showed a log-normal distribution of individual doses, irrespective of the region (typical distribution is shown in Fig. 1). The distribution of the

USSR population was obtained according to the individual dose commitment (see Fig. 2) and in comparison with the analogous doses from natural background radiation (ignoring the technogenic background) /Fig. 3/. It is of interest that the individual dose commitment for the majority of the USSR population (about 250 million people) will not exceed 1 mSv.The calculations show (see Fig. 4) that the dose contribution of this population to the total collective dose commitment for the population of the whole country (278.8 million people) will not exceed 15%. Consequently, the Chernobyl experience shows that the decrease of the lower level of the individual dose commitment down to zero does not practically influence the collective dose commitment.

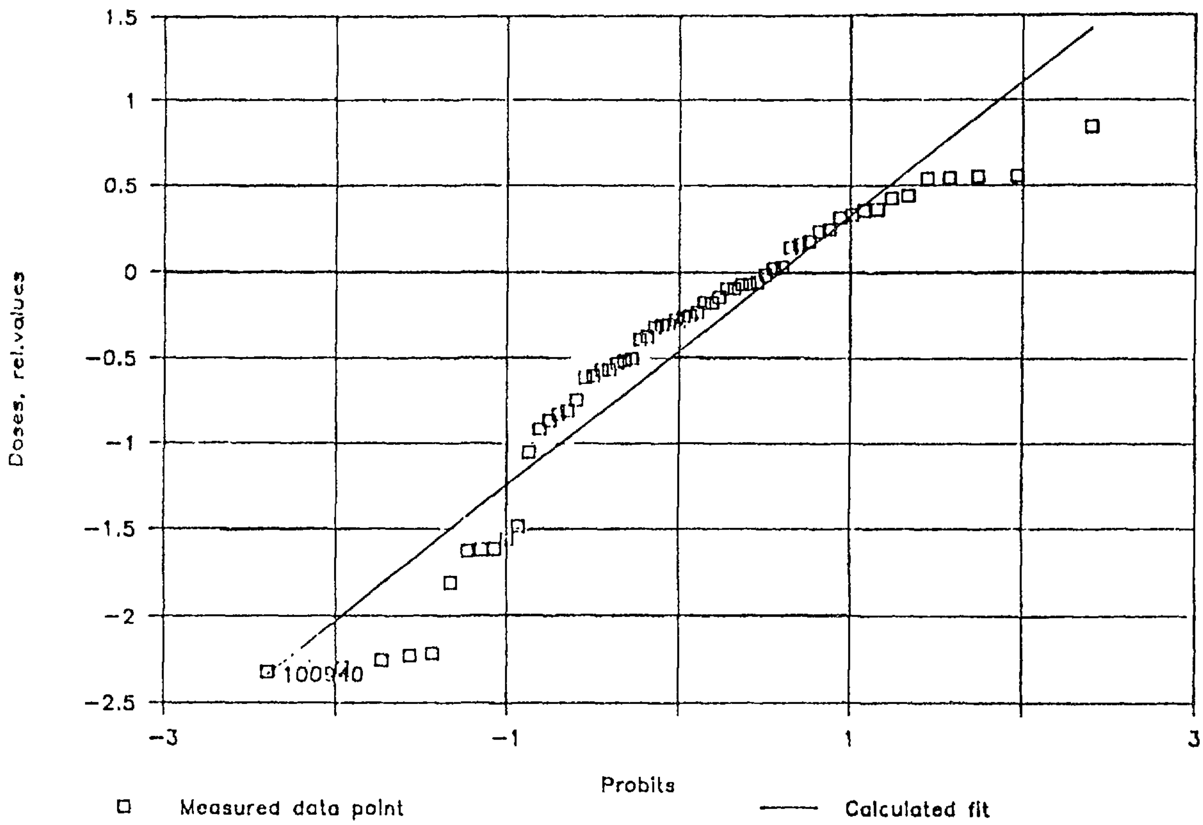


FIG.1. Probability distribution of the individual doses.

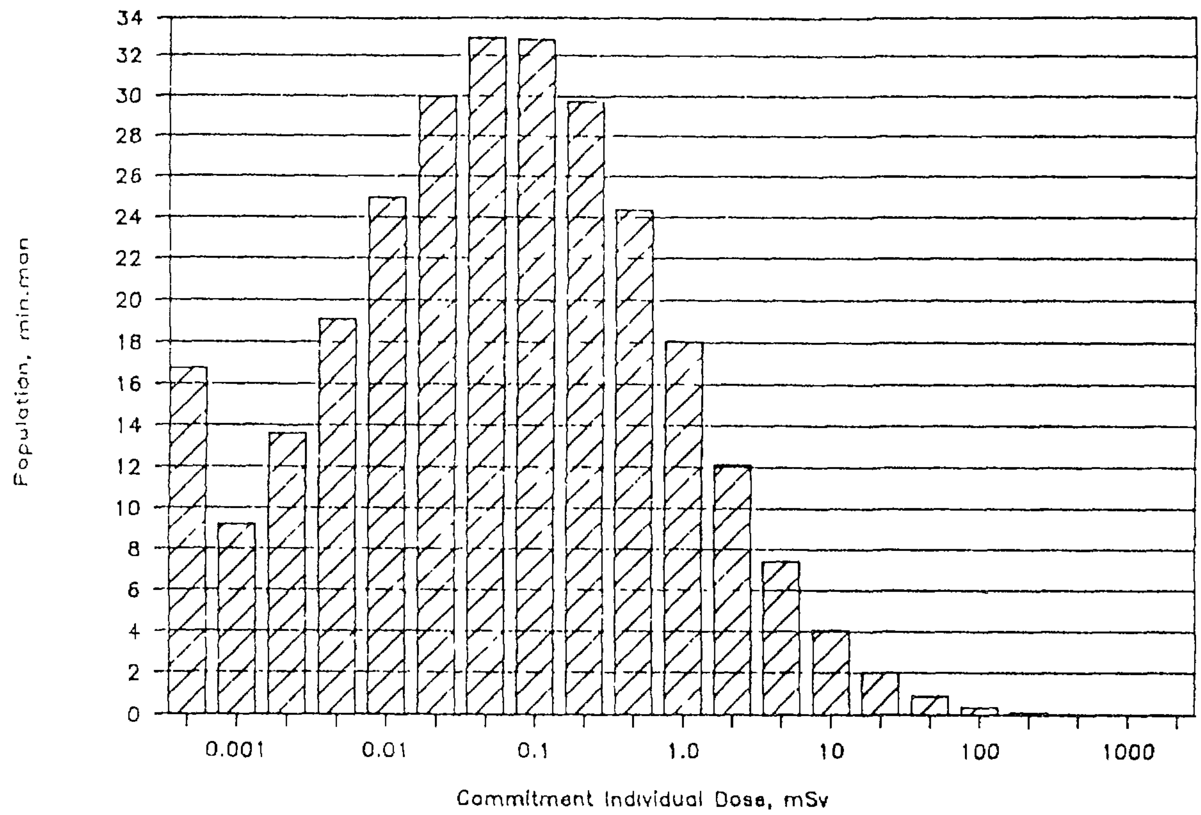


FIG.2. Distribution of the USSR population according to the committed individual doses.

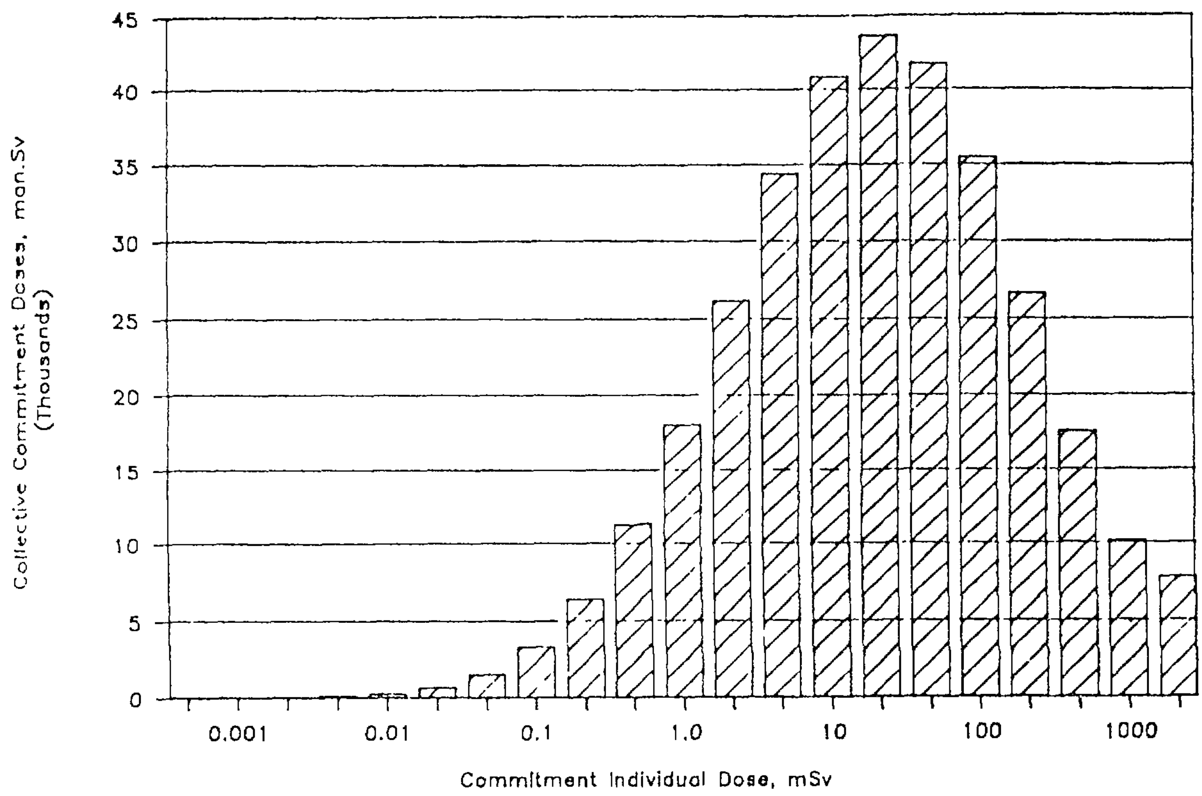


FIG.3. Distribution of the USSR collective committed doses according to the committed individual doses.

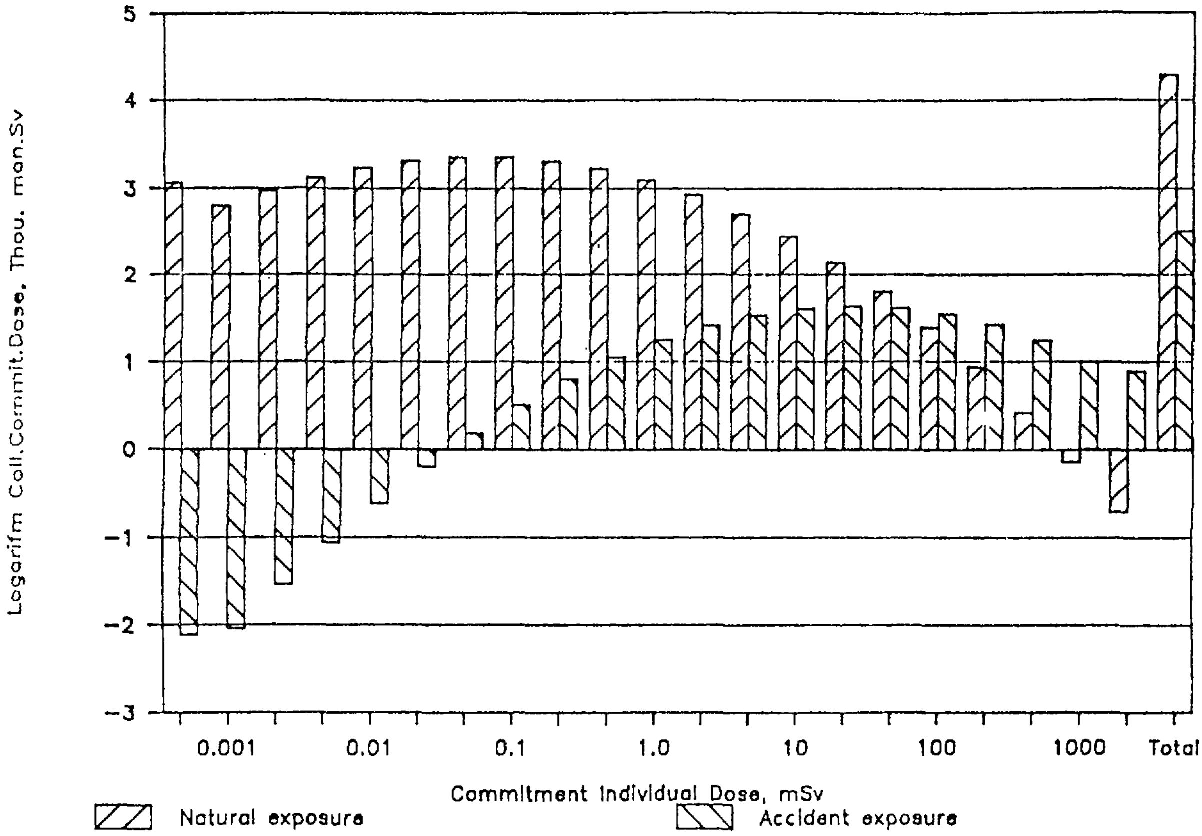


FIG.4. Distribution of the USSR collective committed doses from natural and accident exposures.

It stands to reason to discuss this conclusion in terms of the discussion at the ICRP meeting (Como, Italy, September 1987), where arguments were adduced in favour of setting the lower limit of the individual dose commitment which should be considered as a biologically significant exposure level.

For many reasons, this approach seems to be more realistic than that in current use.

One should also take into account that the original meaning of the collective dose concept predetermines its use in the solution of radiation protection problems and not in the assessment of late effects of accidental exposure.

If, in the framework of our analysis, the lower level of the individual dose commitment is taken to be 10 mSv (which constitutes only about 15% of the corresponding cumulative dose from natural background radiation), one may conclude the following. The expected fatal cancer excess will increase up to 0.23% of the spontaneous level (Fig. 5) (for a population of $7.5 \cdot 10^6$ men with a collective dose commitment of $2.2 \cdot 10^5$ man Sv), the absolute number of predicted cancers decreasing by 30% as compared with initial estimates for a population of $280 \cdot 10^6$ men.

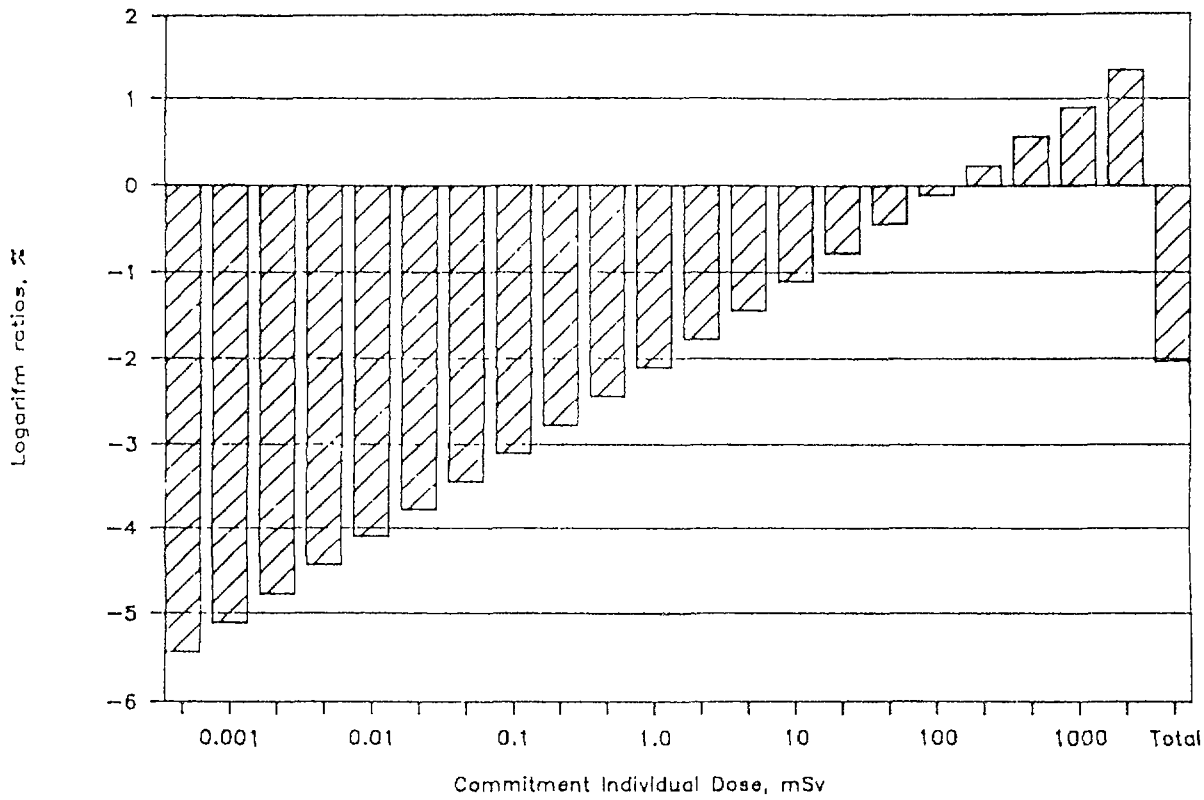


FIG.5. Ratios of rad-induced to spontaneous cancer according to the committed individual doses.

Finally, as appears from these calculations, the present epidemiological methods would fail to register the above malignant tumor excess.

In conclusion, it should be pointed out that a number of radiation protection problems illuminated by the Chernobyl accident have not been touched upon in this report. To these problems which have not yet lost their significance belongs radiophobia.

There is a lot of work to do in this sphere.

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PROTECTION OF HEALTH DURING A LARGE SCALE ACCIDENT

A.E. ROMANENKO

Abstract

The general principles applied in planning measures to protect the population covered four periods: (1) the 24 hours following the accident; (2) 2-7 days after the accident; (3) 2-6 weeks after the accident; (4) the subsequent period.

In order to carry out medical examinations and provide medical care for those who had been evacuated and those living in regions with high levels of radiation, about 2000 doctors, 4000 intermediate-level medical assistants and more than 1200 senior students at medical institutes were involved. In the first period, 230 laboratory-dosimetric mobile teams were set up and more than 400 teams of doctors, including 212 specialized teams for examining children and pregnant women. The epidemic control stations in these regions were supported by shift teams from epidemic control stations in other regions. A total of 330 doctors, 600 intermediate-level assistants, 125 special vehicles and so on were involved.

Over the whole period about 500 000 people were examined, including 100 000 children; more than 500 000 haematological and 54 000 hormonal studies were carried out, and more than 200 000 measurements of iodine and caesium in the bodies of affected individuals were made.

Nuclear power engineering is the reality of the contemporary society. General Secretary of the CPSU Central Committee M.S.Gorbachev declaired that the future of the world economy is hardly imaginable apart of its development.

At the same time notwithstanding technical and technological efforts made in every country to decrease the risk of radiation accidents at nuclear power plants, these risks cannot still be completely avoided.

This is one of the basic problems that the necessity of development and planning of so called " secondary protection level " for the population under accidental conditions.

The experience of Chernobyl accident shows us that questions of protection must be solved in spite of all the efforts and means they demand. These protective measures must be planned and financed in the complex with the design, construction and maintenance of nuclear plants. Populated areas and industrial objects no less than 30 km around the plant must also be specially prepared for the maintenance under conditions of a radiation accident. Some of these measures are:

- material basis for the systems of environmental radiation monitoring, including population control;
- additional hermetization of buildings, both residential and industrial, and construction of radiation shelters;
- availability of iodine compounds; milk products; food stuffs for children;
- material basis for the systems of information and communication; training of the population with the help of special literature, aiming at the prevention of negative socio-psychological reactions, as well as the organization of appropriate behaviour of the population during the initial period of the accident.

Notwithstanding the experience of earlier radiation accidents in different counties the Chernobyl accident due to its severity has brought complicated problems connected with health service for the population of contaminated areas. These problems demanded theoretical considerations as well as quick reactions and decision making.

Chernobyl has demonstrated that the complexity of problems connected with population protection at a transfrontier nuclear accidents require ample international cooperation aiming at ensurance of nuclear safety and population protection.

You know that in May 1986 M.S.Gorbachev have submitted a number of proposals to some international organizations (IAES, WHO, etc.) to work out safety regime for nuclear engineering.

Therefore, summing up the experience of the Chernobyl accident consequences liquidation, we consider it necessary to share it with the national and international organizations, dealing with different aspects of radiation protection.

That is why in this paper we want to touch certain organizational, medical and socio-psychological aspects of the radiological situation that has developed as a result of the accident and some conclusions and recomendations concerning health service.

Complex measures undertaken for the mitigation of the accident consequences had required mobilization of considerable medical resources.

A lot of specialists were involved in examination and treatment of the critical population: 2 000 physicians: 4 000 junior medical personnel; 1 200 senior medical students. During the initial postaccidental period 230 dosimetry laboratories were set up as well as about 400 medical teams, including 212 specialized brigades for examination of children and pregnant women, compiled of specialists in pediatry, obstetrics and gynecology, hematology, endocrinology etc. Sanitary-epidemiologic stations in contaminated areas were reinforced by shift teams from different regions. Totally 330 specialists, 600 junior personnel, 125 specialised transport units were involved.

Iodine prophylaxis was performed to 5 mln people, including 1,6 mln children.

During the whole postaccidental period over 500 000 people were examined, including 100 000 children, over 200 000 tests on iodine and cesium in children were performed including 100 000 children. Over 500 000 hematologic, 54 000 hormonal and 200 000 iodine and cesium tests were performed.

It is necessary to note that while organizing hematologic examinations, we must take into consideration people's attitude of mind based on the widespread conception that radioactivity is connected with hematologic and biochemical alterations.

Special attention was paid to medical care of children and pregnant women, who were evacuated during the first days after the accident and placed to sanatoriums and boarding houses for supervision.

In spite of the extremely complicated radiological situation in July 1986 the preliminary forecast was worked out for the external and internal commitment population doses for the first postaccidental year as well as a number of measures for the decrease of these project doses.

On the initiative of sanitary-epidemiological service, activities of various establishment dealing with radiomonitoring were coordinated. During the whole postaccidental period scientific and applied sanitary - epidemiologic enterprises performed about 3 mln instrumental and laboratory tests of food stuffs, drinking water and environmental samples (only for Ukraine).

As a result of this sample activity actual internal population doses were 5 to 15 times lower than those projected. Mass clinical examinations justify the absense of significant health disorders in the population of critical areas compared to the control.

In addition to the huge work performed by the organs of practical health service, wast research investigations were planned and organized. In Kiev All-Union Scientific Centre of Radiation Medicine was organized within the USSR Academy of Medical Sciences; the Scientific Council on Radiation Medicine was founded.

A complex of technical facilities is being developed, software for the Distributed clinic dosimetric register of individuals subjected to ionizing radiation is initiated as well as special subregisters of the individuals, selected for long-term control.

It is useful to underline that according to the general direction of the social policy in our country the Ministry of Health in 1985 began the organization of total annual medical screening of the country's population.

Our investigations have revealed the following peculiarity of large-scale radiation NPP accidents which may be useful for medical planning: patients with different forms and stages of acute radiation sickness; including combined radiation, mechanical and termal lesions may be found only among NPP personnel and members of resque teams. And the number of these individuals is, as a rule, limited.

For the population of the areas, neighbouring the place of accident, non-stochastic effects are hardly problem, as well as acute radiation lesions.

As for long-term stochastic effects manifesting in excess cancers and congenital defects, they will be the focus of the accident medico-social consequences assessment. The degree of the latter is dependent on the chosen concept: threshold or non-threshold ? So it is first of all necessary to choose more appropriate of the two concepts. However, long-term following of wast population cohorts is necessary after a NPP accident.

This provided favourable prerequisites for the development of dispensary control of the population in contaminated areas. It is clear that the programmes of medical screening were corrected according to the situation with the involvement of dosimetry and special tests.

The peculiarities of the Chernobyl accident required special measures differing in many aspects from many theoretical and practical investigations performed by Soviet and foreign specialists concerning radiation protection under the conditions a severe nuclear accidents.

Variety of accident scenarios connected with their scale and development in time present difficulties for emergency planning.

After the Tree Mile Island (USA) accident in the WHO Brussels meeting Report the accident time development scheme was recommended that consisted of three phases: early, intermediate, and late. However, the Chernobyl accident did not fit this scheme.

It seems reasonable to consider these phases of development of any accident with no regard for any peculiarities of every accidental situation. We suggest that the early period must be considered to be the initial, acute accidental phase, that lasts untill the cessation of uncontrolled releases. In the case of Chernobyl this initial period lasts till May 5, 1986 (9 days since the explosion), then the releases stopped.

Intermediate phase - is a period of various possible duration, when the accident liquidation works on the damaged reactor site are over and this guarantees cessation of further environmental contamination. Moreover, at the beginning of this phase the radiological situation is formed. This phase may last for several weeks or months,depending on the severity of the accident.

Late phase - is the posaccidental or reconstructive period, when the gradual return to usual life takes place. It may last for many years, for medico- social and ecological consequences require long-term scientific investigations which cause a number of peculiarities in the everyday life of the population in the accident area.

Chernobyl accident and its impact mitigation has given us base to suggest that in accidental planning health protection of the population is a prior necessity. Ample range of countermeasures must be planned and performed step by step according to the regular succession that depends on their significance and for the gradual involvement of necessary means. All the emergency measures must be planned for maximum scale project accident with the maximum radionuclide composition, otherwise population may be under the risk of overdosage.

Taking these considerations into account we want to recommend the following staging of the emergency plan:

Stage I : within 1 day after the accident;

Stage 2 : 2 - 7 days after the accident;

Stage 3 : 2 - 6 weeks after the accident;

Stage 4 : 1,5-2 months after.

The duration of the first stage is stipulated on the one hand by the fact that initial accidental releases are as a rule the most powerful and form the majority of the project dose, including inhalation doses from radioiodine on the thyroid gland, which are accumulated rather intensively and on the other hand the efficiency of iodine prophylaxis which rapidly decreases as a function of time.[x]

All these require emergency measures under the conditions of unsufficient information concerning actual radiological situation.

The duration of the stage 2 is dependent on the probability of accident release cessation, radiological situation stabilization, necessity to finish evacuation and perform the initial consequence liquidation measures.

Stages 1 and 2 cover the initial (acute) accidental period (early phase according to WHO terminology) and require special accuracy in planning and readiness of emergency means.

Stages 3 and 4 correspond to the intermediate phase.

Stage 3 is a period of iodine danger, that determine the character of countermeasures as well as medical activities.

Stage 4 completes the intermediate phase of the accident and determines the beginning of the late phase. The expediency of this phase detachment is subjected by the necessity to guarantee the cessation of further environmental contamination on the one hand,

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x Iodine prophylaxis is aimed to block the inhalation dose due to the transient character of this process. For alimentary dose decrease or exclusion alternative countermeasures are used.

and by the necessity to master the radiological situation within the shortest possible time, on the other hand. The latter demands beforehand preparations of material and methodical basis for large scale environmental, food chain and population examinations in the areas contaminated by long living radionuclides.

Further periodization and planning of accident consequences liquidation measures depend on the season of the accident and on the number of other aspects. We consider further planning unreasonable as medical means involved by that time are numerous and enough for all reseach and applied activities. Moreover, time is no longer pressing.

The main tasks of stage 1 are:

1. Preliminary estimation of the accident severety and radiological situation.

2. Emergency aid to the injured.

3. Emergency measures on population protection.

4. Involvement of medical means into the accident consequences liquidation.

Emergency measures are:

- Sheltering of the population, first of all children, pregnant women and nursing mothers in residential or industrial buildings with the maximal possible hermetization. The latter must be taken into account by the authorities while designing buildings on the territories involved into emergency planning. This measure is very effective and does not require large expences especially if the population is prepared and urgently informed;

- iodine prophylaxis, first of all for children. The efficiency of this measure depends on the availability of iodine compounds in convenient form for rapid distribution;

- in some cases evacuation of the population from the most contaminated areas or at least preliminary measures that make evacuation itself fast and easy.

Evacuation is considered to be the extreme measure and is performed only when radiation level causes the exceed of the quote of external dose limit for the first postaccidental year with regard for average daily shielding for the majority of the population.

Assessment of other criteria within one day after the accident will hardly be probable. It must be noted that emergency evacuation without strict organization and preliminary preparations may cause higher body burdens than sheltering before organized evacuation.

Countermeasure decisions are based on the assessment of health consequences as well as detriment connected with the introduced countermeasures, which are determined by two dose levels: lower (beneath it the chosen countermeasure is inexpedient) and upper (when the dose exceeds it, the countermeasure is unnecessary).

In case of Chernobyl due to a number of reasons and for the interest of population protection upper dose limits were decreased. Some of these reasons were on the one hand connected with the difficulties in stochastic effects estimation depending on the chosen conception - linear of threshold, and on the other hand - the complexity of the developing radiological situation and difficulties in its estimation in the first days after the accident.

Depending on the severity of the accident and local conditions emergency plans must include the readiness and emergency development of medical establishments: clinics, specialized medical establishments, mobile means to start health care in the places of evacuated population residence.

These mobile means are:

- radioiodine monitoring brigades;
- brigades of specialists in pediatry, obstetrics and gynecology, endocrinology, hematology etc., for data examination and forma-

tion of critical groups (children, pregnant women, nursing mothers):

- medical laboratory teams for adult population examination;
- specialized teams of medical radiologists, hematologists etc., to reinforce the personnel of local clinics and hospitals;
- reinforcement teams for local sanitary- epidemiological stations;
- brigades of specialtsts with the necessary involvement of psychologists for elusidation of the events to the population.

Main tasks of stage 2 are :

1. Estimation and specification of radiological situation.
2. Selective monitoring of radioiodine in thyroid gland.
3. External doses forecasts formation.
4. Selective radiometry of food stuffs and environmental samples.
5. Medical treatment of injured and necessary aid to evacuated population.

Continuation of radioactive releases may cause significant changes in radiological situation. That is why urgent specification of the contaminated zone borders and the degree of contamination are the basis for adjustment of medical measure plans.

One of the most complicated tasks of this stage is organization of selective thyroid monitoring, first of all for children and pregnant women. It is stipulated by short physical half-life of radioiodine and even shorter effective half-time, especially for children. All these demand urgent measures in complicated conditions of sheltering and evacuation. Only beforhand preparedness of material, methodical and organizational basis may assure reliable and appropriate results that help to specify the radiological situation and selection of principles of further mass population supervision.

The results of iodine monitoring must be analysed on the basis of dosimetry, first of all, of local milk and milk products.

That helps to assess the ratio of inhalation and alimentary contributions to the thyroid dose.

To have reliable data concerning forecasts for external doses both calculation and instrumental methods of radiometry must be actively used.

If they exceed the external dose limit quote for the first postaccidental year the decision about the necessity of evacuation is made.

More complicated task of this stage is control of food stuffs, drinking water and environmental monitoring. This control is necessary for establishment of internal doses and forecasting as well as for the specification of radiological situation.

As soon as means and instruments for this control are located in establishments, subordinate to different ministries and departments, it is clear that coordination and cooperation of these establishments on mutual methodical and organizational base are necessary.

This complicated system of centralyzed collection, generalization and assessment of dosimetry data must be based on two methodical centres: establishments of the State Committee of Hydrometeorology, responsible for environmental control, and establishments of Ministry of Health, responsible for food stuffs control, internal dose assessment and forecasting.

Both centres cooperate to control the functioning of the whole system.

All these require beforehand preparations of material and methodical base, development of organizational principles and distribution of functions and means among different ministries and departments. This was organized during the liquidation of the Chernobyl accident on the initiative of Ukrainian Ministry of Health and by the Decree of Council of Ministers of the Ukrainian SSR.

Main tasks of stage 3 are:

1. Specification and assessment of radiological situation and its forecasts.

2. Development of mass radiometry of thyroid radioiodine, clinical examinations of children, pregnant women and certain contingents of adult population.

3. Enlargement of the variety of environmental samples for radiometry; control of foodstuffs and drinking water, sanitary supervision of restrictive measures maintenance.

4. Preparedness of instruments and means for the control of long-living radionuclides in the environment, food stuffs and population.

For this stage it is useful to note:

- it is necessary to establish organizational and methodical centres on the basis of specialized research institutions. The latter must as well be responsible for preliminary development of uniform medical documentation, worked out according to the programs and scale of investigations, ready for computer processing.

- while preparing the means of long-living radionuclide control it is necessary to spicify the presence and condition of equipment, laboratories subordinate to certain ministries and departments, as well as the programmes of investigations, distribution of functions, the order of centralized data collection, analysis of the results, preparation of reports, development of decision projects according to the situation. These preliminary measures may help to master the situation on the 4th stage and to correct the plans of consequences liquidation.

One of the main tasks of the 4th stage is mass control of radiocesium , forecasting of internal doses and late effects assessment.

Integral part of emergency planning is development of measures aimed at prevention or limiting of socio-psychological proseses, which accompany any radiation accident. We couldn`t avoid it in the Chernobyl situation as well as it had not been avoided during the Three Mile Island accident.

Basic reason of psychological tension, radiophobia and reactive conditions is inability for a man to detect radioactivity with the help of sense organs: as well as low level of radiological knowlege, identification of a power plant accident and a nuclear bomb explosion; missing of contradictory information. All these lead to rumours and fantasies, contributing to the development of tension and inadequate population reactions and behavior, for example, self restrictions in green food stuffs.

These conditions are the reasons of health anomalies and may cause a variety of diseases of non- radiologic origin.

That is why preliminary training and education of personnel as well as of the population of the territories that may be involved into the accident is of great importance for prophylaxis of radiophobic reactions. Population has to know the potential danger of accidents, their character, acute and late radiation effects, protective measures and their effectiveness.

Under the conditions of actual accident population has to be methodically informed about measures taken and main sourses of risk, protective activities and appropriate behaviour.Special attention should be paid to training of medical personnel and enlightenment of intelligensia, which is the main sourse of disturbing information.

Important are the measures preventing deviations from the official information.

SCHEME OF A SEVERE NUCLEAR POWER PLANT ACCIDENT DEVELOPMENT AND ADEQUATE COUNTERMEASURES

Phases of accident (WHO Terminology)	Stages of emergency plan	Radiation sourses	Types of ir radiation	Countermeasures
Early	1 (24 hours after the explosion	Radioactive cloud Body deposition from fallout	External (total) Internal (inhalation)	Timely information(+) Sheltering (+),Respiratory organs protection (+), Body protection (+), Iodine prophylaxis (+), Evacuation (+-), Individual decontamination (+).
	2 (2-7 days after the accident beginning)	Radioactive cloud, Body deposition from fallout, ground deposition, food chain ˣ	External (total) Internal (inhallation,intestinal) External and Internal (adsorption)	Sheltering (+-),Body and respiratory organs protection (+), Iodine prophylaxis (+-), Evacuation (+), individual decontamination (+), limited visiting of supervised zones (+), Control of food stuffs and drinking water (+).
	3 (2-6 weeks after)	Ground depositions	External Internal(intestinal)	Migration of the population (+-), Control of food stuffs (+), Decontamination of the territory (+-). Limited admittance (+-)
Intermediate	4 (after 1,5-2	Ground depositions Food chain	External Internal (intestinal)	Control of food stuffs (+), Decontamination of the territories (+-)

Note: ˣ Depends on the season of the accident
) (+) Applicable and necessary
(+-) Applicable though do not require cost-benefit analysis

RADIATION ENVIRONMENT
AND RADIOLOGICAL PROTECTION

THEORY AND PRACTICE OF ESTABLISHING RADIATION STANDARDS BEFORE AND AFTER THE CHERNOBYL ACCIDENT

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M.I. BALONOV, Yu.O. KONSTANTINOV

Abstract

If the external gamma dose to the whole body or exposure of the thyroid gland does not exceed 0.25 Gy, there is no need to adopt emergency measures which would temporarily disrupt the life of the population. If external exposure exceeds these levels but does not exceed 0.75 Gy, or if the dose to the thyroid gland from ^{131}I exceeds 2.5 Gy, then ad hoc decisions have to be taken in accordance with the actual circumstances encountered. Doses of less than 0.25 Gy are virtually harmless to the individual, a dose of 0.25 Gy is considered potentially dangerous, and at doses of 0.75 Gy for whole-body exposure or 2.5 Gy for local exposure of the thyroid gland, radiation sickness or pathological changes in the gland may occur in some cases.

External exposure doses to the population in the most severely contaminated regions of the Ukraine during the first year after the accident lay in the range 0.7-2.5 rem, and internal exposure doses - assessed from the results of 52 000 examinations - did not exceed 1 rem in 90% of cases. Only in 230 cases did the anticipated doses exceed 5 rem.

The concentration of the main dose-forming nuclides, caesium-137 and caesium-134, in milk products, potatoes, vegetables and fruit produced in the contaminated region outside the 30-km zone was 0.5×10^{-8} Ci/kg.

A system of dose limits and principles of their application as well as radiation protection regulations based on public health legislation of the USSR and Soviet republics and approved by the USSR Ministry of Health in a number of official documents served as a legal basis for measures taken by public health bodies under conditions of a radiation accident at the Chernobyl nuclear power plant. These dosuments include above all the Standards of Radiation Protection (SRP-76), the main Sanitary Rules (MSR-72/80), the Criteria for Taking Decisions on Measures to Protect the Population in the Event of a Reactor Accident, and the Sanitary Rules for Nuclear Power Plant Designing and Operation (SRNPP-79). The above documents were drawn up taking into consideration radiation protection experience gained in the USSR, findings of Soviet and foreign scientists, ICRP and IAEA recommendations. Now, we can say that at all stages of the accident the official documents which regulated the radiation factor proved efficient with regard to sanitary and hygienic as well as medical measures aimed at localizing the accident, to prophylaxis and handling of medical consequences for workers and general public. At the same time, a number of theoretical and practical aspects of standardization appeared to demand further development and, in some cases, special experiments and epidemiological studies.

The SRP-76, MSR-72/80, and SRNPP-79 inclide sections in which dose limits and radiation protection regulations are provided for projected increase of personnel exposure in the management of a radiation accident. The above dose limits and regulations agree with those recommended by the ICRP and adopted in most countries. Their strict observation prevented participants in localization of the accident and decontamination of the plant site and adjoining area from overexposure fraught with serious medical consequences. A tragic exception was the death of a few plant workers within the first minutes and hours of the accident when potential exposure could not yet be predicted. The other measures were all carried out according to an emergency plan brought into force on 26 April, as soon as information on the accident and fire was received.

The current SRP do not set standards for public exposure from routine operations of nuclear power plants. This seems reasonable since to guarantee human rights in this country also means to ensure entire protection of people against harmful effects of productive activity. But the SRP provide the public exposure limitation by the regulation or control of environmental activity (water, air, foodstuffs, etc.), production processes which might result in radioactive contamination of the environment, doses from medical exposure and technogenically increased background caused by construction materials, chemical fertilizers, combustion of organic fuel, etc. The regulation or control procedure is determined by standardization acts legally approved or co-ordinated by the USSR Ministry of Health. In the event of an accident, taking account of its nature and scale, the Ministry of Health may set temporary dose limits and permissible levels for the public and work out sanitary rules to provide living conditions in areas contaminated with radioactive material. To fulfil such a laborious but important task, the Ministry of Health invited a large group of leading scientists and experts, including first and foremost the National Commission on Radiation Protection (NCRP). An analysis of this work will be given below, and now we should dwell on an early stage of the accident when all possible measures were being taken to minimize public exposure, in accordance with the Criteria.

According to the Criteria, if external whole-body gamma exposure or thyroid exposure does not exceed 0.25 Gy, there is no need to take emergency measures that involve the temporary disruption of the living routine of the public. If this level is exceeded but external dose or thyroid dose from ^{131}I do not reach 0.75 Gy and 2.5 Gy, respectively, decisions should be made with allowance for actual conditions. Emergency measures to protect the public (indoor shelter; restriction of time spent outdoors; rapid evacuation; prophylactic iodine distribution; ban on or restriction of contaminated foodstuffs; shift of dairy cattle to uncontaminated pasture or fodder are recommended if external whole-body gamma dose reaches 0.75 Gy or thyroid exposure from radioiodine exceeds 2.5 Gy. The numerical values of the Criteria are supported by the a posterior conclusion that doses below 0.25 Gy are practically safe for an individual, a dose of 0.25 Gy is believed to be potentially harmful, while a whole-body dose of 0.75 Gy or a thyroid dose of 2.5 Gy might result in isolated cases of radiation sickness or thyroid pathological anomalies. The Criteria are in close agreement with those adopted in other countries, exceptions being rather rare. For instance, evacuation is recommended at a whole-body or thyroid dose of 2.5 Gy (Czechoslovakia), at whole-body doses of 0.1-1Gy and thyroid doses of 1-10 Gy (Hungary), at doses of 0.1-0.5 Gy to the whole-body and from 0.3 to 1.5 Gy to the thyroid and other organs (EEC Comission).

At an early stage of the accident, the policy of the Ministry of Health was to avoid public exposure above the Criteria values and, in any case, to prevent the population beyond the evacuation zone from receiving 10 rem over the first year after the accident, i.e. levels much lower than those of the Criteria. Due to the measures taken, whole-body doses for the majority of evacuees (a total of about 115 000 people) did not exceed 25 rem; it was only in some population centres situated in areas most heavily contaminated from the plume that doses happened to reach 30-40 rem. Wide-scale medical examinations which involved 930 000 people, including 696 000 persons thoroughly studied with dosimetric and laboratory methods, permitted the absence of acute radiation sickness among the population to be stated. In conformity with the Criteria, prophylactic iodine was distributed among 5 365 000 people. As a result, thousands of hypothyrosis cases were avoided, whole-body and thyroid exposures were reduced.

As soon as urgent steps had been taken, the efforts of the Ministry of Health were focused on sanitary and hygienic measures to minimize doses to the public from external and , primarily, internal sources of radiation. With this in view, of great importance was prompt determination of temporary permissible levels (TPL), allowing for changes in radiation conditions, to regulate radionuclide contents of foodstuffs and water, contamination of various surfaces, etc.

Because of a major part of ^{131}I in external and internal exposure at an early stage, temporary permissible radioiodine contents of drinking water and a number of foods for the period of the management of the accident were elaborated within the first days and approved on 3 May 1986. These were supplemented with additional standards for staple foodstaffs on 6 May. To avoid excess external and internal public exposures, on 7 May 1986 the Ministry of Health approved TPL of radioactive contamination for various surfaces (premises, transport, equipment, etc.), clothes, footwear, skin, and means of personal protection. Subsequently, taking into account the latest dosimetric data, on 2 June 1986 revised permissible contamination levels, based on established exposure standards, were introduced for ground, road, and outer and inner construction surfaces following decontamination.

Allowing for ^{131}I activity reduction and a growing part of long-lived radionuclides, on 30 May 1986 the Ministry of Health approved the "Temporary permissible levels for the radionuclide content of foodstuffs, drinking water, and medicinal herbs (total beta activity)" which comprised nearly all foods consumed by the public. Since a great amount of fruit and vegetables grown in areas of potential contamination is usually processed, the "Temporary permissible levels for the radionuclide content of canned fruit and vegetables" were established on 19 September 1986. Use of livestock products, which might have been contaminated, in the production of drugs and produce manufactured from enzyme and endocrine raw material necessitated setting standards for finished articles. Therefore, the "Temporary permissible levels for the radionuclide content of medical preparations" were approved by the Ministry of Health on 22 July 1986 and the "Temporary permissible levels for the radionuclide content of endocrine and enzyme raw material" were approved by the Ministry of Health together with the State Agro-Industrial Committee on 19 September 1986.

To improve control of produce manufactured at the enterprises under the State Agro-Industrial Committee, 28 standardization documents were adopted by the above authority and the Ministry of Health to regulate treatment, processing, and preparing for realization of various livestock, poultry, fodder, fur products, etc. Changes in the radionuclide composition, gamma exposure rate reduction since the moment of the accident, and a large-scale decontamination operation all led to the new "Temporary permissible contamination levels for the skin, underwear, clothes, transport, machinery, and means of personal protection" (14 October 1986) and "Temporary permissible contamination levels for roads, populated areas, outer and inner construction surfaces following decontamination" (26 October 1986) in which lower permissible exposure rates and beta contamination levels for surfaces were set.

A package of timely measures and strict observance of TPL reduced doses to the public by 70% and prevented mass diseases among highly concentrated populations. As a result, external doses to the population of the most heavily contaminated areas of the Ukraine over the first year after the accident were 0.7-2.5 rem and internal doses did not exceed 1 rem for 90% of 52 000 people studied. Only for 230 persons dose commitments reached 5 rem. In the areas of the Russian Soviet Federative Socialist Republic which adjoin the accident zone, external doses over the first year were estimated to range from 0.5 to 5 rem. From the radiocaesium content of the body investigated in 90 000 inhabitants, internal doses due to these nuclides were shown to average 1.5 rem over the first year. Average doses of total external and internal radiation to the population of all contaminated areas did not, therefore, exceed 10 rem established by the Ministry of Health as a temporary dose limit.

As more specific information was obtained and the radiation situation changed for the better, temporary dose limits for the public were revised. Thus, by the end of 1987, as compared with summer of 1986, the radiation conditions in areas affected by the accident became far less serious. And the Ministry of Health set a dose limit of 3 rem/year for total (external and internal) exposure over the year 1987. Large-scale expeditionary studies showed a more than 10-fold reduction of gamma background by the end of 1987. The concentration of ^{137}Cs and ^{134}Cs (major dose-contributing nuclides) in dairy products, potatoes, vegetables and fruit produced in contaminated areas beyond a 30-km zone was $0.5 \cdot 10^{-8}$ Ci/kg. Even the highest values registered in potatoes, vegetables, and fruit were 4-10 times lower than those of the TPL of 30 May 1986. The radionuclide content of bakery products and cereals also appeared to fall below the above TPL values. For lack of uncontaminated fodder, the highest milk and meat (primarily beef) contamination levels still exceeded the TPL, particularly in the private-owned sector. However, according to a system of restrictions, such products were not allowed for sale or use at public catering extablishments. Based on actual data, average dose estimates for all population areas did not exceed 3 rem/year, a standard established by the Ministry of Health. Moreover, internal doses from radiocaesium were 0.3-0.7 rem/year and lower, thus indicating an improved radiation situation and high effectiveness of measures taken to reduce intakes of radionuclides with food. Therefore, in December 1987 the NCRP reviewed the TPL of 30 May 1986 and suggested new TPL to fit the radiation situation. The new TPL were calculated for the total radiocaesium activity with allowance for routine daily consumption of principal foodstuffs. For all foods, the new TPL correspond to internal doses of no more than 0.8 rem/year, and actual dose commitments may appear lower by a factor of two or more. Comparison of TPL-88 and those of 30 May 1986 shows a 2-20 fold reduction of values for the majority of foodstuffs.

It should be stressed that TPL-88 provide the most strict caesium standards as compared with other countries (e.g. for milk: USA, $2.4 \cdot 10^{-7}$; UK, $1 \cdot 10^{-7}$; Finland, $2.7 \cdot 10^{-8}$, USSR, $1 \cdot 10^{-8}$ Ci/l).

Therefore, it follows that the standardization and control system adopted in this country permitted an effective solution of sanitary and hygienic tasks caused by the Chernobyl accident. Nevertheless, in setting temporary dose limits and permissible levels under variable radiation conditions, a number of unsolved theoretical problems arose, some of which require urgent research. Scientific foundation of dose limits and permissible levels is known to demand the solution of a complex of problems relative to modelling the migration of accidentally released radionuclides through various environmental pathways to man and formation of doses to critical organs due to intake of radionuclides by inhalation or ingestion. Also of significance is potential external exposure from a radioactive cloud or radionuclides deposited on various surfaces (soil, vegetation, buildings, etc.). Model descriptions of these processes are fairly well formalized. Of great help in solving the above problems were the recommendations presented in ICRP Publication 30 with supplements (Limits for Intakes of Radionuclides by Workers). However, since this Publication is intended first and foremost for workers, many questions remained unsettled, e.g. those related to model coefficients and parameters applicable for different age groups. Special attention should be paid to experimental studies of parameters which describe the passage of various soluble and insoluble radionuclide-containing compounds through the gastrointestinal tract. An important element for determining permissible levels of food contamination is standardization of average daily and annual diets in different regions Experience of the Chernobyl accident has confirmed an opinion formerly expressed by the NCRP that such ICRP concepts as benefit-detriment analysis with a body of mathematics proposed, linear relationship between dose and stochastic effects, and risk factors of late effects and weighting factors based on this concept lack scientific foundation and cannot be applied in practice. At the latest ICRP meeting in Como (Italy), the International Association on Radiation Protection (IARP) made critical remarks against the ICRP on these issues. Assessment of late stochastic effects of an accident on the basis of collective doses and risk factors derived from a linear relationship without threshold seems to be particularly absurd. The above issues all require a most thorough research and remain in sight of the NCRP and other experts concerned with the radiation factor regulation.

RADIOACTIVE CONTAMINATION OF WATER ECOSYSTEMS AND SOURCES OF DRINKING WATER

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Abstract

The contribution of aqueous components to the individual and collective doses received by the population as a result of the accident at Chernobyl in 1986 did not exceed 1-2%. In the first few days after the accident, the total beta radioactivity of the water was 1×10^{-7} Ci/L. Subsequently, the concentration of radionuclides in the water fell steadily and throughout 1987 was stable at $1\text{-}3 \times 10^{-10}$ Ci/L. The highest recorded figure was 4×10^{-9} Ci/L in May 1986 caused by iodine-131 (for the Dnepr).

Four main radio-hygienic problems caused by the Chernobyl accident may be settled as follows:

- urgent assessment, study of dynamics and forecast of external gamma-radiation changes in different regions of the country caused by passing of radioactive clouds and radioactive fallout;

accidental monitoring of radioactive contamination of rivers and open water basins used for drinking water supply, industrial and recreation purposes, with the aim of development of short- and long-term radio-hygienic measures;

- mass radiological monitoring of all the links of food chain: soil - agricultural products - foodstuff components and ration in general for population of territories contaminated with fission products;

- mass measurements and forecasts of external and internal irradiation levels caused by the accident.

All the above-mentioned problems determining the radiological situation in the country for both the scale of research and medical measures, and resources necessary for solution of these problems are too ample to discuss in one paper. Therefore, in this paper we will present only important general points. Results of the detailed analysis of radio-hygienic situation will be given in coming paper. The heterogenic structure of the radioactive contamination of the huge territories is the main feature of the radiological situation. Specifics of radiological situation in different regionss required different population protection measures. They are:

- evacuation of population from the towns of Prip'at, Chernobyl and settlements of 30-kilometer zone around Chernobyl NPP where the major dose loads were determined by external irradiation;

- introduction of standards on water and foodstuffs radioactive contamination and systems of hard control of their observation on the territories, where the major doses were determined by internal irradiation.

In this paper we stress the features of radiological siruation connected with the radioactive contamination of aquatic ecosystems and sources of drinking water.

The radio-hygienic situation on the aquatic objects of the country formed after the Chernobyl accident had a regional specifics. Thus, because of geographic situation the main water basins are to the south of the NPP site. At the same time most intensive fallouts (due to complicated weather conditions) were formed in northern direction.

During the assessment of radiological situation in the northern part of Ukraine and nearby territories of Byelorussia and Russian Federation, the main attention was paid to the quality of water from small rivers and reservoirs, and to supervision of local water sources.

During the examination of radiological situation in southern territories of Ukraine the main problems were connected with the assessment of status and providing of protective measures for large basins, producing water for drinking, industrial and technological purposes, irrigation, used for fish-breeding and fishing, sports and recreation.

Even in the first year after the accident radioactive releases affected the status of the large reservoirs of Ukraine: the rivers Dniper, Dnestr, Southern Bough et. al. However the first obtained data about the radioactive substances content and the radioisotope composition of water allowed to determine that the hard supervision and large-scale measures would be necessary only for Dniper basin.

Thus, on the territory of the Russian Federation that was affected by the Chernobyl accident as a result of the meteorological conditions in May 1986, the main drinking water source for three large cities (Kiev as well) is the Desna. However all the territories with high fallout density of fission products are situated out of the basin of this river, beyond natural watershed, and small rivers flowing there (Trubezgh, Snov, Iput', Besed') are the Dniper tributaries above the Kiev reservoir.

The small rivers in Byelorussia (first of all the Braginka) flowing through the contaminated areas are not the objects of drinking water supply. However the level of silt contamination, and enhanced content of radioactive substances in water during 1986-1987, as well as negative results of radio-hygienic assessment of soil status over their basins required including of these factors into the "Dniper-river hydrosphere" system of radiological monitoring.

The Dniper is the largest reservoir of Ukraine; it's water is used by half of the republic population for various purposes. On the territories irrigated with water from this river most agricultural products are obtained; about one third of wheat, some vegetables, rice etc. harvest is collected here. Because of these reasons the questions of Dniper water quality monitoring, development of forecast for it's changes, perspectives of possible water usage for various purposes became a subject of state interest since the first days after the Chernobyl accident.

As far as the radioactive contamination of drinking water sources may cause a certain danger for health of population and also taking into account the huge scale and certain specifics of necessary protective measures, which require participation of specialists from different ministries and departments, the general supervision was conducted by the Ministry of Public Health of Ukraine and it's local offices.

Thus Ministry of Public Health of the UkSSR with assignment of the Council of Ministers of the UkSSR launched coordination of efforts of Ministries of Land-reclamation and Water Industry of the UkSSR; Ministry of Housing and Communal Services; Ukrainian administration of hydrometeorology and environmental monitoring, and offices of sanitary and epidemiological service concerning laboratory water quality monitoring. They also took part in providing of "Dniper-river hydrosphere monitoring program" launched later.

Analysis of joint laboratory investigations show that maximum radiation levels in the water from the Kiev reservoir were observed during the first days after the Chernobyl accident (total beta-activity had reached the value of I E-7 Ci/l). Next IO days radiation level in water was unstable (5 E-9 - 6 E-8 Ci/l).

During the following period radionuclide concentration in water was decreasing all the time: since 27 May till 20 July I986 it was detected as I-2E-9 Ci/l; since 20 July till 20 November I986 - fluctuated in the range of 3-7E-IO Ci/l, and since the end of November and during the whole I987 - stabilized at the level of I-3E-IO Ci/l.

Totally during the period since the Chernobyl accident by means of sanitary and epidemiological services, research institutes, laboratories of all ministries and boards of the Ukrainian SSR territory only, more then 300 thousand water analyses from open reservoirs, centralized water supply systems and bore-wells were conducted; among them - more than 3 thousand gamma-spectrometry and radiochemical analyses.

It was investigated, that the level of total radioactivity of water during May-June I986 was determined by I-I3I content (in May contribution of this radionuclide into the total water radioactivity was 80-90%, in June - up to 30%). Since the second half of June (according to disintegration of I-I3I- the level of total activity of water from the Kiev reservoir was determined by the presence of relative short-livers: Sr-89, Ba-I40, Ru-I03, Ce-I4I and Ce-I44, Zr-95 (and their daughters), as well as Cs-I34 and Cs-I37 to minor extent.

Radionuclide concentration in water (except I-I3I that had the established temporal content normative) did not exceed the levels, determined in the SRS-76.

Level of radioactivity in the rivers Prip'at and Braginka, radiologicaly critical tributaries of the Dniper in the upper Kiev reservoir area during I986 was about I0 times higher than typical values for the reservoir; during I987 - 2-3-6 times higher.

Radiological situation of the rest tributaries in the upper Kiev reservoir area (rivers of Uzh, Teterev) during all this period was more stable, however in some cases, after the heavy rains in June-August I986 followed with washing down from surfaces, radioactivity of water was 2-3 times higher than is typical for Kiev reservoir level.

Radio-hygienic situation in the Desna-river basin (the main Dniper tributary) was at the same level as in Kiev (up to the moment of accident it was about one half of drinking water supply of Kiev) during the whole period was more stable. The highest level of radioactivity (4 E-9 Ci/I) was registered in May I986, mostly contributed by I-I3I. Since August - September I986 radioactivity of this water basin was at the level of I E-I0 - I E-II Ci/I.

Drinking water in the centralized systems of water supply corresponded to the pre-accidental levels during all this period. Taking into account fluctuations of Kiev reservoir water radioactivity observed in May I986, Dniper water supply was closed and the 2.5 million population of this city during the summer I986 was supplied by drinking water from the Desna and bore-wells.

The Dniper on the territory of UkSSR is the totally controlled reservoir. All in all there are six reservoirs in the Dniper cascade: Kiev, Kanev, Kremenchug, Dneprodzerzghinsk, Dniper and Kachovka reservoirs. Influence of the radioactive contamination of Kiev reservoir on the radiological situation was detected over all the area of Kanev and Kremenchugh reservoirs, however in August I986 the radioactivity level was stabilized within 2 -9 E-IO Ci/I. Kremenchugh reservoir during the year played the role of a buffer in the cascade reservoir system (including to design of the dam, large dead volume of the reservoir). Water quality dynamics is shown on fig.I. After the high-flood in I987, in spite of it's shallowness, water radioactivity level in Kremenchugh reservoir decreased and now is not higher than 5 E-II Ci/l.

In the rest of reservoirs of the Dniper Cascade, according to total beta-activity of water, it's quality is similar to the typical level, however content of Cs-I37 is several times higher, Sr-90 - about IO times (I E-II - 7. E-I2 Ci/l). According to the above-mentioned, the possibility of prolongation of period of the Dniper water usage for irrigation and first of all for rice cultivation was investigated. The Cs-I37 level of 5.0 E-II Ci/l was adopted as a control one and during all the post-accidental period, according to data of sanitary service, it was not exceeded in any region of water usage.

However radiological situation over water objects is determined not only by content of fission products in water. As a result of processes of sedimentation the major part of radioactive

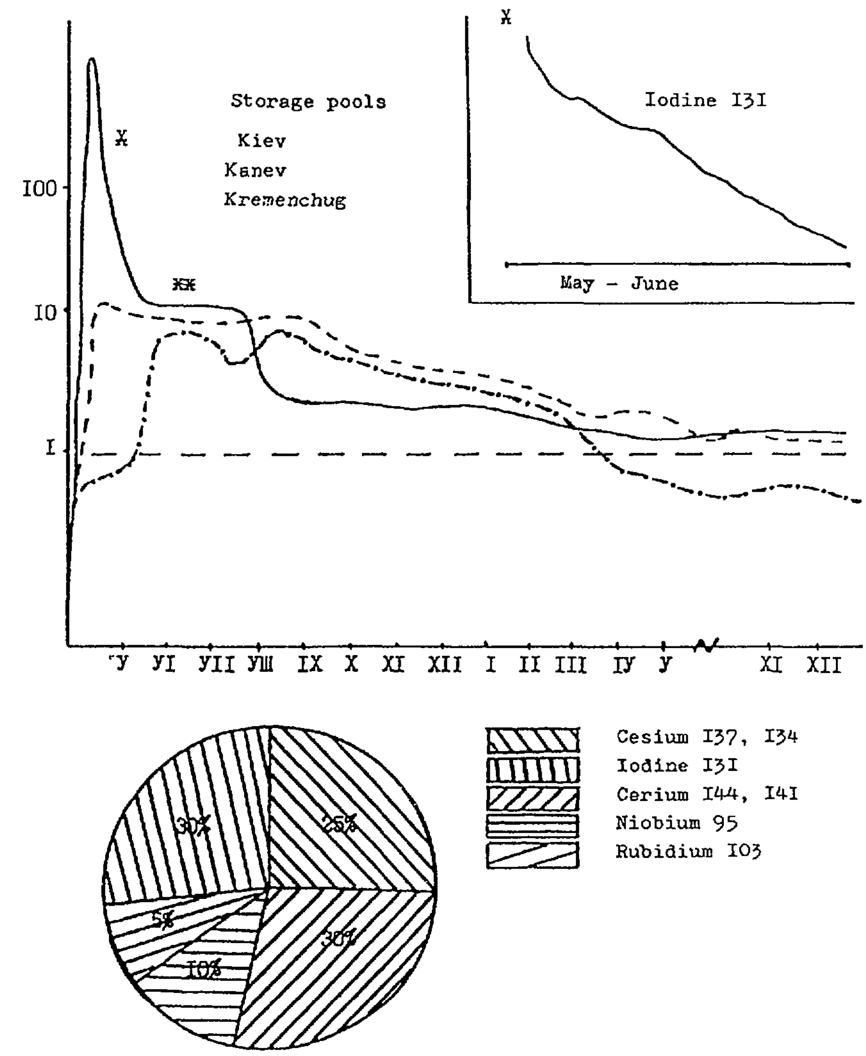

FIG.I. Dynamics of water quality changes in aquatic objects.

substances, entering water surroundings, relatively soon falls out into the bottom depositions. Radionuclide concentration in these depositions is I0-I000 times higher than in water of all reservoirs of the cascade. Especially clear is the ratio of these radionuclides in Kiev reservoir, small rivers of northern part of Ukraine, nearby areas of Byelorussia and Russian Federation. The constructed coffer-dams, special traps and reservoir dams played the positive role in decreasing of spreading of silts from the Kiev reservoir and rivers Prip'at, Braginka et. al. Thus, silt radioactivity in the tail-water of Kiev HPP in summer I986 was 50-I00 times less than at I00 kilometer distance from the coffer-dam.

Results of conducted radiological monitoring were the basis of measures for securing the stable water supply of towns of Dniper cascade, additional measures for cleaning of the open water supply objects, enhancement of the construction drinking water preparation objects.

According to the fact that all the riverside territories of reservoirs of the Dniper cascade are widely used by population in recreation purposes, departments of health protection conducted special target program for assessment of radioactive contamination of these territories. As a result of assessment of these additional doses, which will be accumulated by population, the recreation usage of this territories was permitted without limitations (excluding, of course, territories around Kiev reservoir in 30-kilometer zone and nearby areas). According to requirements of sanitary service, on all the beaches the complex of preliminary sanitary measures was conducted aimed at mitigation of small contaminated spots with the radiation level exceeding the standard established for this area. It was noted that these measures are necessary for beaches of Kiev reservoir and somewhere at Kanev reservoir.

Special attention was paid to local water sources in rural regions: pits, draw-wells, bore-wells. On these territories the measures to improve hermetization of these water sources, to prevent contamination with radioactive substances were conducted. During May - August 1986 in all settlements situated on the territories, where high densities of long-liver fallouts were registered, centralized systems of water supply, using the water from underground well-protected sources were constructed.

To sum it up it is noteworthy to mention the following. Radiological situation in general, particularly aqua-environmental situation on the reservoirs - the major sources of water for drinking, industrial, technological and recreation purposes, was satisfactory, in spite of the large scale of the Chernobyl accident.

Radiological situation on the aquatic objects, situated on the territory of Ukraine, Byelorussia and nearby regions of Russian Federation has strict heterogenic structure. Because of both geographic features of Chernobyl NPP site situation, and concrete weather conditions, aquatic objects of Ukraine were more sensitive to the consequences of the accident, though higher levels of radioactive fallouts were registered on some territories of Byelorussia and Russian Federation.

Highly effective were protective measures over existing water sources and reserve ones; hydrotechnological measures prevention of radioactive contamination spreading; introduction of the hard radiological supervision and hygienic normatives of radioactive substances content in drinking water and foodstuffs.

As a result the water component contribution into individual and collective doses accumulated during I986 due to Chernobyl accident did not exceed I-2%.

INTAKE OF RADIONUCLIDES THROUGH FOOD CHAINS AS A FACTOR IN THE EXPOSURE OF THE SOVIET POPULATION AFTER THE CHERNOBYL ACCIDENT

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Abstract

In the first few days after the accident, a standard (of 1 x 10^{-7} Ci/L) was established for the concentration of iodine in milk, calculated to ensure that the dose to the thyroid gland would not exceed 30 rem. Temporary permissible levels for the concentration of radioactive substances in 24 types of food, water and medical material were established and implemented on 30 May 1986. The highest concentrations of radiocaesium in milk recorded in 1986 were 3-5 x 10^{-7} Ci/L. Unrestricted consumption of that milk could have led to a daily intake of 3000-5000 x 10^{-10} Ci of radiocaesium. Those individuals who had consumed such milk were identified.

The average levels of radiocaesium per region did not exceed the emergency standards. The actual concentrations of radiostrontium in food products did not exceed the temporary permissible levels calculated for this dose and in most cases were 10-100 times less as a result of the control measures which were implemented. Standards, monitoring and classification of foodstuffs were introduced to reduce the internal exposure dose by a factor of 10-30, down to levels which were not only in line with the temporary limits but also with the radiation safety standards (NRB-76).

The concentration of strontium-90 in all the main food products studied was relatively insignificant - namely about 0.3-3% of the radiocaesium concentration.

The intensive discharge of radioactive gases and aerosols from the damaged unit at the Chernobyl Nuclear Power Station (CNPS), which continued 10 days, had led to the contamination of the area with a complex mixture of radionuclides in different directions and at great distances from the CNPS. It has already become customary to distinguish three branches of the radioactive trace: northern, southern, and western. ^{131}I radionuclide was the main dosage factor for the population in the first days and weeks. The presence of this radionuclide in milk was detected already on the second and third days after the accident. In the first weeks, the concentration of

^{131}I in some samples reached $1 \cdot 10^{-6} - 1 \cdot 10^{-5}$ Ci/l. The greens, including sorrel, spinach and spring onions, showed approximately the same level of contamination with ^{131}I.

Within the distance of the near radioactive trace - up to several dozens kilometers from the CNPS - the total amount of beta active substances contained in the water of some ill-equipped draw-wells reached 2.10^{-8} Ci/l. However, in most draw-wells, as well as in open reservoirs used for water supply, the content of these substances in water did not exceed the normal level. By the end of 1986, the ^{131}I content in milk and other foodstuffs had decreased.

As shown by soil and vegetation analysis, the fallout of nuclides from the radioactive cloud was followed by their noticeable fractionation, which became especially apparent at distances upwards of 15-30 kilometers from the damaged unit. Thus, a considerable increase in the concentration of ^{137}Cs and ^{134}Cs radionuclides (tenfold or more) was observed in the northern branch of the radioactive trace. It should be added that the radioactive trace was patchy. When matters were tackled concerning the protection of the population from internal radiation exposure after the decay of ^{131}I and its dropout from food chains, the emphasis was laid on the areas located within the zone of northern radioactive trace (upwards of 150 kilometers from the CNPS). Inside this zone, the caesium patches had covered the poor peat-boggy and sward-podzolic sandy and sandy-loam soils of the Polesye area, which are distinguished for their decreased capability to fix caesium.

Temporary permissible levels (TPL) of the content of radioactive substances in 24 types of food, water, and herbs, became effective as of May 30, 1986. With due account of the feasibility of mass technical monitoring, the TPL were aimed at measuring the total beta-ray activity. During 1986-1987 radiological units of the sanitary-and-epidemiologic service network under the USSR Ministry of Public Health had carried out several hundred thousand check-up measurements. The monitoring and rejection were performed also by departmental services of enterprises engaged in production of foodstuffs, as well as by laboratories under the State Agro-Industrial Committee of the USSR. Apart from these pooled data, this report contains the results of nearly 10,000 gamma-spectral and radiochemical measurements carried out by the Institute of Biophysics under the USSR Ministry of Public Health and the Leningrad Institute of Radiologic Hygiene under the RSFSR Ministry of Public Health.

The radionuclide composition of soil and vegetation in the vicinity of the CNPS (to the north and north-east of the station) is presented in Table I.

As shown by analysis of the data in Table I, radionuclides of cerium - ^{144}Ce, and niobium - ^{95}Nb, constitute a considerable part of radioactive fallout in the southern areas of the Gomel Region, located in the close vicinity of the CNPS; while caesium - ^{137}Cs and ^{134}Cs, and ruthenium - ^{106}Ru account for a major share of nuclides in the localities situated to the north and north-east (Bryansk Region) of the station. The difference between radioactive compositions of the soil and the grass is not substantial. This testifies to the decisive role played by the air and secondary dust routes in the radioactive contamination of herbaceous vegetation.

The pattern of radionuclide contamination of staples of diet (Table 2) is somewhat different. Practically, as follows from Table 2, the radioactivity of milk and meat (the content of natural potassium - ^{40}K - is not taken into account) is determined by the amount of radiocaesium. In 1986, the $^{137}Cs/^{134}Cs$ ratio in soil, grass and all foodstuffs was 2:1. Apparently, ^{106}Ru practically did not migrate from soil into food

Table 1. Radionuclide composition of soil and grass

Place of sample obtaining	Date	Object	Radionuclide composition							
			^{144}Ce	^{106}Ru	^{137}Cs	^{134}Cs	^{95}Nb	^{140}La	^{90}Sr	^{131}I
North of Gomel' region	July I986	Soil	9,3	I7,0	40,3	I8,3	I,7	0,05	I,0	undetected
		Grass	6,6	9,4	53,9	26,5	3,2	0,I	I,3	undetected
South of Gomel' region	July I986	Soil	25,3	I0,3	9,I	5,0	23,I	0,06	0,7	undetected
		Grass	24,0	8,3	I5,6	7,4	2I,7	0,8	I,4	undetected
South of Mogilev region	May I987	Soil	-	I2,0	62,3	25,0	-	-	0,7	-
		Grass	-	6,0	64,5	26,0	-	-	3,0	-
West of Bryansk region	June I986	Soil	8,0	28,0	30,6	I5,2	8,0	6,0	I,0	5,0
		Grass	-	-	56,6	28,3	-	-	-	I,0
	July I987	Soil	8,0	20,0	43,2	I6,6	I,0	-	2,5	-
		Gr ss	-	I,0	6I,4	23,6	-	-	7,5	-

Table 2. Radionuclide composition of foodstuffs established as a result of investigation conducted in northern areas of the Gomel Region in the summer periods of 1986 and 1987 (percentage of the total contamination activity)

Foodstuffs	Year of sampling	Radionuclides (percentage)						
		^{144}Ce	^{106}Ru	^{137}Cs	^{134}Cs	^{95}Zr	^{95}Nb	^{90}Sr
Milk	1986	-	-	66.3	33.1	-	-	0.5
Meat	1987	-	-	71.1	27.4	-	-	1.5
Root-crops	1986	-	0.57	65.0	32.0	0.11	0.72	1.5
Potatoes	1987	-	-	71.5	27.5	-	-	0.3-1.0
Vegetables and fruit	1986	17.6	7.0	32.6	14.6	7.5	10.1	1.2
	1987	-	-	71.5	27.5	-	-	0.3-1.0

Note: "-" - undetected.

chains. In the summer and fall of 1986, those food products which were exposed to direct contamination from the air (such as vegetables, fruit and berries) along with radiocaesium, revealed considerable amounts of ^{106}Ru and ^{144}Ce.

The content of strontium radionuclides - ^{90}Sr - in foodstuffs examined in areas located within all the three main branches of the radioactive trace, was relatively low - about 0.3-3 percent of that of Cs radionuclides (Table 3).

Table 3. Average ^{90}Sr content in some foodstuffs (n . 10^{-12} Ci/l, kg). The data were reported by radiological departments of sanitary epidemiologic stations.

Region	Milk		White bread		Potatoes	
	1985	1986 (II-IV quarters)	1985	1986 (II-IV quarters)	1985	1986 (II-IV quarters)
USSR	2.9	17.0*	4.2	9.9	3.8	8.2
RSFSR	3.3	21.0	6.1	6.2	4.3	6.0
European part of the RSFSR (center)	3.4	50.0	5.2	13.0	4.1	11.3
Ukr.SSR	2.6	23.8	5.1	19.1	3.7	14.0
BSSR	5.4	55.0**	2.4	62.6	6.2	38.0

Note*. Without data for the Gomel and Mogilyov Regions of the Byelorussian SSR; ** According to the results of III-IV quarters.

As shown by the data presented in Table 3, the USSR's average level of contamination of foodstuffs with ^{90}Sr has grown noticeably. In those areas of the RSFSR, Ukr.SSR and BSSR, which were contaminated with radioactive substances, the increase in its concentration was much higher - by about an order of magnitude. However, average ^{90}Sr levels in foodstuffs in these republics remained small - substantially lower than those levels which could cause an excess over the daily dose allowed by SRS-76. The average ^{90}Sr levels in some foodstuffs for III-IV quarters of 1986, presented in Table 3, are in approximate agreement with the content of global ^{90}Sr revealed in foodstuffs in 1964-1965, while the content of this nuclide remains lower as compared to the ^{137}Cs level (Table 4).

Table 4. Average content of Cs radionuclides in staple foodstuffs and total daily diet in 1985* and 1986

Region	Milk 1.10^{-10} Ci/l		White bread 1.10^{-10} Ci/kg		Potatoes 1.10^{-10} Ci/kg		Daily diet**** 1.10^{-10} Ci/day	
	1985	1986 (II-IV quarters)	1985	1986 (II-IV quarters)	1985	1986 (II-IV quarters)	1985	1986
USSR (as a whole)	0.05	17.8**	0.06	0.74	0.05	1.2	0.11	11.2
RSFSR	0.04	33.4	0.07	0.31	0.05	0.2	0.12	20.6
European part of the RSFSR (center)	0.06	93.8	0.05	0.44	0.05	0.23	-	-
Ukr.SSR	0.05	9.7	0.12	2.0	0.07	1.14	0.13	9.2
BSSR	0.28	245.4***	0.08	3.7	0.18	19.7	0.56	164.7

Note: *1985 columns present ^{137}Cs levels; 1986 columns present both ^{137}Cs and ^{134}Cs levels; ** Without data for the Gomel and Mogilyov Regions of the Byelorussian SSR; *** samples were taken predominantly in areas most heavily contaminated with radioactive substances; **** temporary permissible levels (TPS, effective as of May 30, 1986), SRS-76 and standards of the EEC countries, 330 and 270.10^{-10} Ci, respectively.

The data presented in Table 4 testify to a considerably increased ^{137}Cs content, as against the 1985 figure, in all foodstuffs produced after the accident, especially in milk.

Increased level of this nuclide in foodstuffs was observed in all regions of this country, with its most pronounced growth in the BSSR where, due to the prevalence of Polesye type soils, the level of global ^{137}Cs in milk was several fold higher in comparison with the country's average figure. At the same time, in 1986, the country's average daily diet, as well as that in the above-mentioned major regions, showed radiocaesium levels substantially lower than those allowed by SRS -76. The ^{137}Cs intake in the most heavily polluted areas is characterized by the data presented in Table 5.

The data presented in Table 5 show the actual levels of ^{137}Cs and ^{134}Cs intake with the diet by the human body. It should be noted that in all cases the average radiocaesium levels in each district did not exceed normal values. An abrupt decrease in the content of radiocaesium in the diet took place in August 1986 (as compared to July of the same year), which is accounted for by the introduction of a more stringent norm for Cs content in milk (1.10^{-8} Ci/l instead of 1.10^{-7} Ci/l). During the first post-accident year - till June 1987 - the average intake level in the areas polluted with radioactive substances was by about an order of magnitude lower than the norm which allowed the internal exposure level of 5 rem. This is explained by the fact that, due to rigorous control, the actual levels of radiocaesium concentration in foodstuffs did not exceed the TPL calculated for this dose. For the most part, these levels were 10-100 times lower.

The role played by products of animal origin as having the Cs-accumulating property is represented in Table 5. The rigid norm prescribed for milk (as of August 1986) reduced the cont-

Table 5. Actual average levels of ^{137}Cs and ^{134}Cs daily intake with diets by the human body in one northern and three southern districts of the Gomel Region.

Food routes of ^{137}Cs intake by the human body	1986, July	1986 August*	1987, June
Daily intake of ^{137}Cs by the human body with foodstuffs, with due account of the monitoring and rejection, n . 10^{-8} Ci/day	6.36	2.04	1.53
Daily intake of ^{137}Cs by the human body as percentage of the level allowed by TPL as of May,30 1986 (percent)	19.3	6.2	4.6 **
Contribution of some foodstuffs into the daily ^{137}Cs intake by the human body (percent)			
Milk	75.5	23.5	15.7
Meat	19.6	61.2	40.8
Fish	-	-	3.4
Fruit and berries	4.6	14.4	19.2
Potatoes	0.1	0.3	16.2
Vegetables	0.03	0.01	3.1
Bread and bakery products	0.09	0.3	1.3
Other products	0.08	0.2	0.3

Note: * In August 1986 the temporary permissible level of the content of radioactive substances in milk was reduced tenfold – to 1.10^{-8} Ci/l; ** One year after the accident (before May, 1987) the average content of radioactive substances in the diet amounted to about 1.10^{-6} Ci, which agrees with the annual internal exposure dose received by the whole body -- 0.5 rem.

ribution of milk to the total internal exposure dose. However, in "natural" conditions, i.e. without rejection, in the areas contaminated with radioactive substances, milk may account for upwards of 75 per cent of radiocaesium taken in by the human body with food. As shown by calculations, with the level of contamination of milk reaching /1:2/. 10^{-7} Ci/l, it accounts for 90% (or even more) of the intake of Cs contained in daily diet.

It was established that, in actual conditions of this or that populated locality, the ^{137}Cs intake by the human body depends on how thoroughly the recommended protective measures are carried out, rather than on the density of fallout of this particular nuclide. The actual levels of the radionuclide intake by the human body could also be influenced by the fact (not taken into account in Table 5) that the traditional diet structure,which had been taking shape in these areas for many decades, was frequently upset: using their own discretion, people restricted the consumption of meat and dairy products, believing that these foodstuffs mostly accounted for the Cs intake by the human body.

As to their contribution into the population Cs exposure level (with no rejection), foodstuffs may be arranged in the following order: milk, meat, fruit (stone fruit, apples) and berries (currants, gooseberries, wild berries), potatoes and vegetables, fish, mushrooms, bread. A high radionuclide content was detected in tea, and a number of lots were rejected.

In 1986, in areas located in the immediate vicinity to the CNPS, as well as in the most heavily contaminated sections of "caesium patches", the inspection bodies had to reject, along with milk and meat, up to 20-30 percent of samples of cultivated berries, stone fruit, table greens, and about 10 percent of fruit. Potatoes remained "clean" both in 1986 and throughout 1987. As shown by the examination carried out in 1987, the entire produce gathered from personal plots fully complied with the requirements. Among the products which still continue to be rejected there are certain percentages of milk and meat, as well as wild berries, mushrooms and fish, some samples of which showed Cs contents exceeding the TPL several tenfold. The highest concentrations of radiocaesium in milk were detected in 1986 and amounted to (3-5). 10^{-7}Ci/l. Systematic consumption of such milk without any restrictions would have led to the daily Cs intake of 3,000-5,000.10^{-10}Ci. A number of people who used such milk (pensioners, cattle-breeders) were revealed during examinations some of which involved the use of methods of ^{137}Cs detection in the entire body with the aid of individual counters of man (СИЧ). These people (numbering 28) continued, in spite of the prohibitions, to use milk from their own cows which had received fodder contaminated with radioactive substances, as well as mushrooms and berries picked up inside the polluted areas. According to estimates made on the basis of data about the content of radiocaesium in milk and other foodstuffs, the maximal internal exposure doses, caused by Cs in the above-mentioned persons, could reach the level stipulated by the norms for emergencies, or exceed it 1.5-2 times. This conclusion agrees with the results of mass direct measurements of ^{137}Cs content in humans. By comparing these data with those of Table 5 one can conclude that the introduced norms, inspection and rejection made it possible to reduce several fold the internal exposure dose received by humans in polluted areas, while in certain cases this figure decreased 10-20 fold, at times reaching levels meeting the requirements of not only TPL worked out for emergencies, but also those of SRS -76.

Correct calculation of internal exposure doses, based on one-time ^{137}Cs content measurements, requires information on the intake dynamics. One can take stock of the pattern of this dynamics with the aid of the data presented in Table 6.

Table 6. Dynamics of ^{137}Cs content in milk, on a per-unit basis, with the concentration recorded in July 1986 taken as a unit

Area	Year, month	July 1986	Sept. 1986	March 1987	May 1987	June 1987	Sept. 1987
Gomel Region:							
- south		1.0	0.72	2.09		0.69	0.57
- north		1.0	0.46	0.42	0.29		0.34
Bryansk Region		1.0	0.73	0.43*	0.39	0.62	0.41

Note: * The average value for the stable fattening period (November 1986 - April 1987).

The data presented in Table 6 reveal the general trend towards a gradual purification of milk of radioactive substances. Reduced contamination of second-harvest grasses, observed towards the end of the range fattening period (September 1986), accounted for the decreased Cs content in milk. In the period of stable fattening of cattle in the regions where hay, gathered in areas polluted with radioactive substances, made up a substantial percentage of fodder, milk showed increased contamination levels (southern areas of the Gomel Region). During the same period in the Bryansk Region, due to the use of "clean" fodder, the contamination of milk with radioactive substances fell off noticeably. In early summer of 1987, after fattening on winter crops, Cs content in milk slightly increased.

The relationship between the density of Cs contamination of soil and the content of this radionuclide in milk is shown in Table 7.

Table 7. The relationship between the density of ^{137}Cs contamination in different regions and its content in milk taken in these regions from privately-owned cows in summer and fall of 1987

Region	District	Contamination density (Ci/km^2) at which Cs content in milk is 1.10^{-8} Ci/l
Gomel	Vetka	4.9
	Khoyniki	3.0*
Mogilyov	Cherikov	5.2
Bryansk	Novozybkov	4.4

Note: * This value could be affected by unauthorized supplies of hay from the 30-km evacuation zone around the CNPS.

It should be noted that Table 7 presents data for milk from privately-owned cattle. Milk from publicly-owned cattle which is on fodder from cultivated pastureland and, besides, receives greater amounts of cleaner concentrated fodder, in the same area is, as a rule, 2-3 times cleaner than milk from private cows grazing on roadsides, in the forest, etc. Milk from publicly-owned cows, which met the TPL radiocaesium content requirements, could be received in 1987 in the areas with the contamination density of 10-15 Ci/km^2. It is likely that in the future, as caesium is fixed in the soil, clean milk will be also available from cows fed on fodder from more heavily contaminated areas. The content in soils of various assimilable forms of caesium is shown in Table 8.

Table 8. The content of mobile forms of ^{137}Cs in different types of soil in 1986-1987 (as a percentage)

Region	Soil type	Forms of Cs (as a percentage of total content)		
		Exchange*	Accessible** for plants	Tightly bound
Gomel	Sward-podzolic	15.0	28.5	71.5
	Sandy	(1.6-27.2)	(1.4-46.5)	
	Peat-boggy	6.3	14.9	85.1
Mogilyov	Sward-podzolic	27.2	33.0	67.0
	Peat-boggy			
	Sandy	(16.0-38.5)	(18.1-47.9)	
Bryansk (Novozybkov District)	Sward-podzolic, sandy and sandy-loam	--	15-31	69-85
Tula (Plavsk District)	Chernozems	--	8-18	82-92

Note: * The part of caesium displaced by 1n ammonium acetate solution; ** the part of caesium displaced by 3n hydrochloric acid and 1n ammonium acetate solution.

The data presented in Table 8 make it possible to conclude that a substantial proportion of radiocaesium is still radily accessible for plants. This proportion is approximately equal to that of global caesium detected in the soil in the 1970s. As shown by analysis of data obtained, there is no clear-cut relationship between the capability of caesium to pass from the soil into vegetation (fodder grasses) and the type of soil, as well as the proportion of assimilable caesium available in the soil (Table 9).

This may be attributed to the fact that the major part of caesium fallout covering unplowed soil lies in its uppermost layer - it has not yet penetrated the deeper layers

Table 9. ^{137}Cs transfer coefficients (K) in "soil-grass" and "grass-milk" links of the food chain in summer periods of 1986 and 1987, and in the pre-accident period (1970), Ci/kg/l /Ci/kg

Sampling sites	Grass/soil K			Milk/grass K		
	1970*	1986	1987	1970*	1986	1987
Gomel Region	0.5-4.5	0.83	0.25	0.35	0.31	0.34
Mogilyov Region	-	1.5	0.7	-	0.27	0.30
Bryansk Region (5 western districts)	-	1.8	0.26	-	0.22	0.34

Note: * According to "Global Caesium-137 Fallout and Man". - M.: Atomizdat Publishers, 1974, by A.N.Marey, R.M.Barkhudarov, N.Ya.Novikov, in 1974 in the Pavlovsk District, Tula Region, the grass/soil K was 0.002 (for chernozems).

(on natural pastures, by the fall of 1987 more than 80 percent of ^{137}Cs had remained in the upper 2-cm layer of the soil). On the other hand, the role played by agrotechnical measures (amelioration, fertilizer application, lime pretreatment) should not be ruled out, either, for it is these measures that result in decreased Cs mobility in soils (Tables 10 and 11).

Table 10. Coefficients of transfer of ^{137}Cs into foodstuffs depending on agrochemical measures taken in 1987, Ci/kg/Ci/km^2

Fallout density, Ci/km^2	Agrochemical measures	Potatoes, K_n $n \cdot 10^{-8}$	Vegetables, K_n $n \cdot 10^{-8}$
Less than 15.0	Conducted	0.06 (0.092-0.007)	0.05 (0.007-0.01)
More than 15.0	Not conducted	0.06 (0.018-0.003)	0.007 (0.022-0.004)

Table 11. ^{137}Cs transfer coefficients in the "soil/grass" link of the food chain (K grass/soil) depending on the type of pasture

Area	Number of farms examined	K, grass/soil , Ci/kg/Ci/kg			
		Pasture type		Farm category	
		Natural	Cultivated	Private-owned	Public-owned
Gomel Region	112	0.41 (0.75-0.16)	0.26 (0.51-0.04)	0.39 (0.78-0.15)	0.15 (0.36-0.03)

The obtained data, partially presented in Tables 10 and 11, make it possible to draw the conclusion that, coupled with agrotechnical measures, the cultivation of pastureland leads to a ten-fold reduction of Cs content in agricultural produce. In 1987, the grass/soil transfer coefficients were considerably lower as compared to the corresponding 1970 figures. The higher 1986 coefficient (Table 9) does not represent a true degree of the transfer of caesium from the soil into the grass. The likely explanation is that fodder grasses were contaminated with caesium from the air rather than soil, as well as due to the secondary dust formation. This also accounts for the fact that in 1986 the milk/grass coefficient was lower than usual (0.22-0.27) because non-organic ^{137}Cs from the air is assimilated by the cow's body to a smaller degree than that passing through the root system of the grass and incorporating into tissues of plants.

The coefficients of transfer of Cs radionuclides from the soil into some other agricultural crops, cultivated on Polesye type soils in the Bryansk Region, were as follows

$\left(\frac{Ci/kg}{Ci/km^2}\right)$: grain - $4.8.\ 10^{-9}$; potatoes - $(1-2).\ 10^{-11}$; cucumbers - 6.10^{-12} ; tomatoes - $(1-4).10^{-11}$.

Essentially the same on sandy soils of the above type in all areas, the Cs transfer coefficients are at the same time much higher (by several orders of magnitude) than those on heavy-loam chernozem soils characteristic of southern areas of the Tula Region.

Outside the northern branch of the radioactive trace, no large contaminated areas, comparable to those described above, have been revealed. Further investigation is needed to predict the routes of radiocaesium migration in food chains in Ukrainian-Byelorussian Polesye and the rate of "purification" of these chains. Also important is the problem of rehabilitation of soil within the 30 km zone, where, along with radiocaesium, alfa active nuclides - ^{239}Pu and ^{90}Sr - may be significant as far as protection against internal exposure is concerned.

In the first post-accident weeks, radioactive iodine was the major factor of internal radiation exposure. Later on, internal exposure levels were determined by ^{137}Cs and ^{134}Cs.

In areas where the ^{137}Cs contamination density exceeds 10-15 Ci/km^2, it will be impossible, for a long time to come, to receive milk conforming to the standing radiation safety norms and good for use without being processed.

In areas with maximum densities of Cs radionuclide fallout, the intake of these radionuclides with local agricultural products by the human body (without dairy products), starting from the autumn of 1987, was (6-8). 10^{-10} Ci/day, which corresponds to the annual internal exposure doses - approximately 100-150 mrem.

Starting from the autumn of 1987, complete control of foodstuffs of vegetable origin (with the exception of mushrooms and wild berries) received from products grown within the "caesium patches" became unnecessary.

CHARACTERISTICS OF RADIONUCLIDE INTAKE BY INHALATION

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Abstract

Internal exposure of all organs other than bone tissue by inhalation of a mixture of radionuclides virtually ceased by the end of the first year after the accident. Comparatively intensive fallout from the radioactive plume took place in the town of Pripyat' late in the evening and during the night of 26-27 April 1986. The density of contamination in certain streets of the town by iodine-131 at the time evacuation began was estimated to be of the order of (1-70) x 10^6 Bq/m^2 (30-2000 µCi/m^2). This gives a value of intake by inhalation of (0.3-20) x 10^6 Bq (10-700 µCi), which corresponds to an absorbed dose to the thyroid gland in adults of 0.2-14 Gy (20-1400 rad). The actual results of measurements were significantly lower than the maximum estimate.

The main contribution to the predicted 50-year dose equivalent commitment for bone tissue is from transuranium elements, and exposure during the first year corresponds to about 1/4 of the maximum permissible dose for occupationally exposed persons.

INTRODUCTION

As a result of passing of radioactive cloud over the town, it`s inhabitants were affected by the following radiation factors:

- external beta-gamma-radiation from the cloud;
- internal irradiation as a result of radionuclides inhalation from the cloud;
- external beta-gamma-radiation of nuclides contaminating horisontal and vertical surfaces;
- internal irradiation by inhalation of secondary aerosols, coming from contaminated surfaces;
- internal contamination as a result of radionuclide intake with contaminated food-stuffs.

The effect of the latter may be excluded by means of organization of providing the population with " clear " food products. Thus inhalation intake of radionuclides during the passing of radioactive cloud may present for some population groups the major factor, causing subsequent internal irradiation.

Knowledge of dynamics of releases from the damaged reactor to the atmosphere together with the information about meteorological conditions of radiation transport that were changing, allows a relatively accurate description of radionuclide concentration alternations in nearground air layer, though only in case of rather large-scale averaging. This approach can be hardly considered a suitable method for realistic assessments of inhalation uptake role as a factor of internal irradiation, for the application of this large-scale averaging to the concrete territory may lead to mistakes (IO and more times). The second possible source of quantitative information is the practical results of measurement of radionuclide concentration in inhabited areas. This relatively correct information exists for large cities (Kiev, Minsk etc.).

It is evident, that the results of individual measurements are most informative. The measurement of dose rate from thyroid gland as the simplest kind of individual examination, allowing to assess the commitent absorbed dose in this organ were conducted for hundreds of thousands inhabitants of contaminated areas of Russia, Byelorussia and Ukraine. Authors of this paper had no possibility to summarize the huge array of data, which will be accessed for many years. Here we discuss the results of individual investigations which were conducted directly by the authors and which are directly connected with the subject of this work - the inhalation uptake. First of all there are results of investigations of individuals from Pripiat` - the Chernobyl NPP personnel town, who were evacuated to the relatively clear regions approximately in 1,5 days after the accident.

Estimated maximum assessments.

In case of absence of data about radionuclide concentration in nearground air layer the evident relation may be used:

$$U = Q \cdot W / V,$$

where U - expected inhalation radionuclide uptake during total time of fallout, Bq (μCi);

Q - measured contamination density of the area, Bq/ m^2 (μCi/ m^2);

W - 0.33E- 3 m^3 / sec - respiration rate of a reference man;

V - radionuclide deposition rate on surface, m/sec.

This formula, of course, should not be used for the areas which were contaminated as a result of local rains, falling during the radioactive cloud passage. In literature the "dry" deposition rate is considered usually to be V=0.05-0.005 m/sec.

Observations of average daily concentration and fallout intensity, conducted since May till August 1986 in Kiev show that deposition rate for I-131 was in the range of 0.003-03 m/sec; for isotopes of cesium - 0.01-0.3 m/sec, isotopes of cerium - 0.006-1.3 m/sec. As for I-131 we assumed deposition rate and consider it to be of overestimated level V=0.001 m/sec. Thus, the following formula may be used for the assessment of possible inhalation uptake of I-131:

$$U <= 1/3 \cdot Q$$

Using the data concerning the maximum density of I-131 contamination, registerd in April-May I986 the following assessments may be obtained according to this formula (see table 1).

Table 1. Density of the I-131 contamination of some towns in April-May I986

City	Gomel`	Donetsk	Kiev	Minsk	Mogilev	Pinsk	Poltava
Q,kBq/m^2	2400	7.4	480	15	59	780	18
U,kBq	810	2.5	160	5	20	260	6
U/ALI	20	0.07	4	0.1	0.5	7	0.2

According to SRS-76 the ALI for I-131 aerosols is considered to be 3.7E4 Bq (I.0 µCi). In assumption that inhalation of one ALI of I-131 aerosols leads to irradiation of thyroid gland of 15 mGy, the assessed commitment absorbed dose will be about 0.33 Gy for Gomel and about 50 mGy for the largest city - Kiev. We emphasize the maximum nature of the e assessments which did not take into consideration a lot of factors, decreasing actually observed values of individual doses. Assessment of the latter will be given below.

General characteristics of the discussed individual examination results.

Absence of peroral radionuclide uptake for every examined individual had been additionally confirmed with the results of individual inquest concerning the behavior regime since the moment of the accident till the beginning of examinations. Results of this inquest show that in spite of relatively low statistics of the examination, collected data about behavior regime are typical for the evacuated population of Prip`at, excluding a small group of those, who were in more extreme conditions because of their individual resons.

The following experimental data, obtained with various methods and by different groups of investigators are discussed further:

1) commitment adsorbed dose in thyroid gland caused by iodine isotopes for 210 evacuated inhabitants of Prip`at, including 75 kids; data were obtained on 3-10 May I986 due to measurement of gamma dose rate from the thyroid gland, selectively intercompared with the results obtained with two-channel "iodine" spectrometer;

2) commitment adsorbed dose in thyroid gland for 650 adults from Prip`at, mostly the NPP personnel, who remained in the regime similar to the common regime of the population during the pe-

riod before the evacuation; however the professional factor should not be totally excluded*;

3) results of radiometry of excrete samples from 64 persons who were on business trips in Prip`at and were evacuated with the inhabitants of the town and returned home (to Leningrad); for 4 of them the detailed radiochemical analysis (I6 nuclides) of excrets was conducted;

4) results of examination with whole body spectrometers and radiochemical analysis of Sr-90 and alpha-emitters in excrets of 189 individuals evacuated from Prip`at, who stayed not nearer than Chernobyl and used only "clean" food;

5) the data about 75 persons who were evacuated from the most contaminated settlements, were used for the comparison of inhalation and peroral radionuclide uptake;

Dynamics of radiation conditions in Prip`at since the beginning of the accident till the evacuation of the population.

According to the measurements of gamma dose rate, conducted by Korobeynikov in about 30 fixed points with the interval 2-3 hours, the location of Prip`at close to the damaged NPP unit (3-6 km) determined, to the great extent, heterogeneous time and spatial picture of the development of the radiation conditions over Prip`at. Behavior regime of people differed too.

It is known that primary release did not affect Prip`at. Further "tranquil" flow of radioactive substances from the damaged reactor under the calm meteorological conditions caused the relatively momentary passage of the rare radioactive streams with the rather small cross- section, which contaminated the earth surface.

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* urgent examination of this group was conducted by V.L. Korobeynikov.

Relatively more frequent fallouts from the radioactive streams in the Prip`at zone happened in the evening and at night of 26 - 27 April, when people were sleeping in their flats. The density of contamination of some streets with I-131 up to the moment when the evacuation was launched was (1 - 70) $\times$ 10^{-6} Bq/ m^2 (300 - 2000 μCi/ m^2). According to these values the inhalation uptake estimated using the discussed formula were (0.3-20) x 10^{-6} Bq(10-700 μCi) and thyroid dose (for adults) - 0.2-14 Gy (20- 1400 rad). Practical results of measurements were sufficiently less than the maximum assessments.

Results of the individual examinations.

The practical results of I-131 incorporation measurements for all the mentioned groups caused the following distribution of the individual absorbed doses (the iodine short-livers were taken into account).

Table 2. Individual adsorbed dose distribution for examined groups

Examined group	Number / fraction of those who belongs to the certain dose interval, Gy			
	0.15	0.15-0.75	0.75-I.5	I.5- 3.0
210 evacuants	140 (66.6%)	65 (31%)	3 (1.4%)	2 (1%)
75 kids, average dose-0.25 Gy	41(54.7%)	31(41.3%)	2 (2.7%)	1(2.3%)
135 adults average dose-0.14 Gy	99(73.1%)	34(25.1%)	1(0.9%)	1(0.9%)
650 individuals from the NPP personnel average dose 0.21 Gy	416(64.0%)	214(32.9%)	17 (2.6%)	3(0.5%)

Higher individual doses for the personnel in comparison with the adults from evacuated population may be explained by the character of their professional activity before measurements. It is noteworthy that among the examined there were individuals who did and did not use iodine drugs.

Relative contribution of peroral radiation uptake into the total food-chain uptake may be compared with the inhalation before the conductment of any sanitary and hygienic measures according to results of I-131 incorporation measurements for inhabitants of two settlements which got under the primary radioactive cloud. None of them used iodine drugs (by the results of the individual inquest). This contingent was divided into two groups separately for each settlement. Individuals belonging to group 1 did not use local milk; group 2 used this milk. Evidently, assumption of the fact that pure inhalation uptake is a dominant for individuals from group 1, at least does not understate the role of this factor in rural conditions. Commitment thyroid dose for both groups may be characterized with the following data (see table 3).

Table 3. Commitment thyroid dose

Settlement index	Group /number of examinated/	Average dose (cGy)	D1/D2 rate
I	1/15/	90+-12	2.6+-0.5
	2/31/	236+-34	
II	1/14/	41+-9	2.2+- 0.6
	2/15/	91+-15	

Represented data show, that the contribution of inhalation consumption into the total food-chain uptake was less than 30%. It is noteworthy that data ontained from this groups relate to the postaccidental period (not more than IO days after the accident) when the food-chain uptake even of I-131 was not expressed in full scale.

The first excrete samples from those who had been on business trips came to the laboratory on the 4-th day after the accident*. Contamination of feces with different radionuclides (related to Zr-95) on the 4-th day after the accident was as follows (see table 4).

Table 4. Radionuclide content in fecal samples on the 4-th day after the accident

Nuclide	Sr-89	Y-91	Zr-95	Mo-99	I-131	Te-132	Cs - 134	Cs-137	Ba-140
Content, related to 1	4	1.5	1	1.1	0.1	1.5	0.15	0.15	2.4

Nuclide	La-140	Ce-141	Pr-143	Ce-144	Pm-147	Nd-147	Pu-239	Am-241+Cm-242
Content, related to Zr-95	2.3	1.9	2.2	1.9	0.1	2.2	0.016	0.027

Certain enrichment (related to Zr-95) of the feces with Sr-89, Y-91, Ba-140, Ce-141, Ce-144 in comparison with the nuclide composition of the sample, that was taken on 28 April 1986 from the radioactive stream from the NPP and the environmental contamination is possible. Content of Mo-99, Te-132, Cs-134, Cs-137 was the same. Relative content of I-131 in feces was significantly less. Difference in radionuclide composition apparently was caused by both the processes of radionuclide transfer from respiratory organs to body liquids and the different relative content of radionuclides in various radioactive streams, passing over the town and determining the actual inhalation uptake. The second reason should be considered the main one.

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* Zvonova I.L., Korelina N.F. and Shvydko N.S. took part in the obtaining and processing of these data.

The averaged results of the radionuclide composition determination in the twenty-four-hours mass of excrements from 2-4 examined individuals are shown in fig.1. The elimination rates on the 1-st day of examination (4-th day after the accident) for each examined individual were assumed as 1. The continuous curve shows the decorporation rate for mixture of 4 nuclides, estimated in accordance with the lung model of the ICRP for aerosols of standard dispersion (AMAD 1 μm) concretely for each nuclide and related to 1(on the 4-th day). Isotopes of Sr,Mo,I, Cs and Ba in these estimations were considered to belong to the dissolution class D, the rest to class - W. Taking into account the fact of proximateness of the ICRP model, possible deviation of the dispersion of inhaled aerosols beyond the standard value, the conditional character of the nuclide classification on dissolution classes - the reliability of the results, shown in fig.I may be considered satisfactory. Therefore, for all the 64 examined individuals the commitment effective equivalent doses were

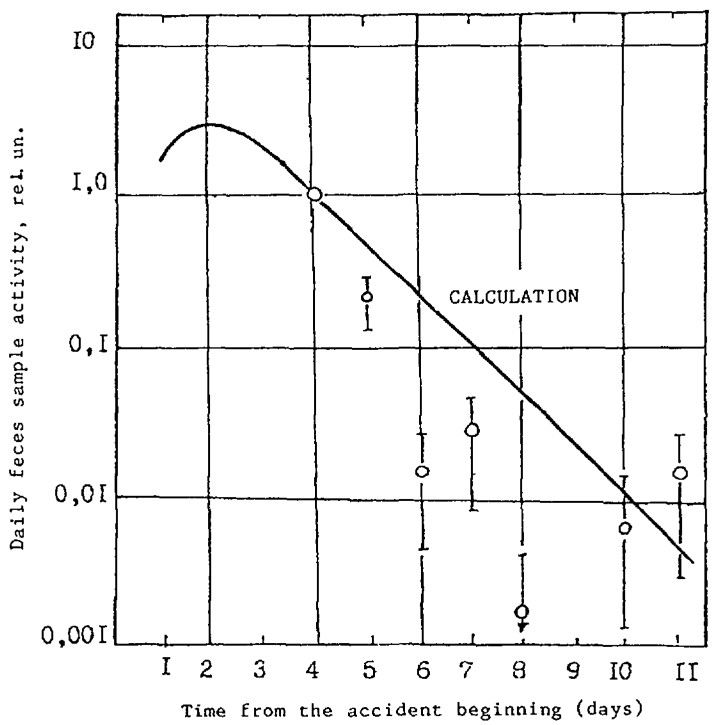

Fig. 1. Observed and estimated dynamics of the total beta-activity of feces.

estimated, using the method of the reverse calculation of the primary inhalation for every radionuclide according to the ICRP model.

The contribution of the thyroid dose into the total dose was calculated separately, using data of the contamination of the thyroid gland with I-131 obtained with gamma-spectrometer precalibrated with the phantom. Correction on the alternative short-livers contribution into the dose was made according to the estimated composition of the fuel.

The results of assessed thyroid doses of those who were examined depending on the time spent outdoors (referring to the results of inquest - for the period since the accident till the departure from Prip`at only) are shown in fig.2. The individuals who did not and did follow iodine prophylaxis were detected also.

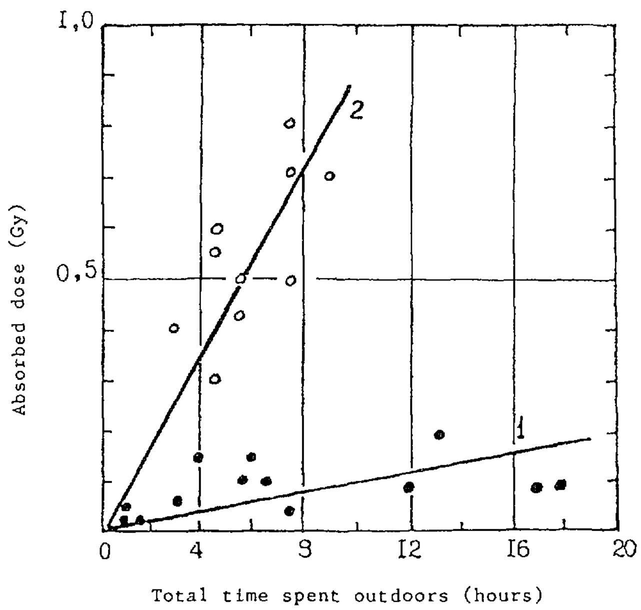

Fig. 2. Thyroid dose - total time spent outdoors curve.

On fig. 2 curves 1 and 2 were plotted with the method of linear regression and correspond to the following relationship between the thyroid dose and the time spent outdoors: D=0.1t and D=0.01t for those who did and did not follow prophylaxis respectively.

Dose D is represented in Gy, time- in hours. Hence, according to the represented relationships, the practical effectiveness of the iodine prophylaxis for the observed groups may be characterized with the protection coefficient of 10. Those, who during their stay indoors had the windows opened and those who in the intermediate point of the evacuation were affected with releases were not taken into exerption represented on the fig.2. These individuals had the highest radionuclide content. This phenomenon may be explained under the assumption that the contribution of the mentioned additional factors into the equivalent dose is the major one. Experimental points should be shifted rightward on the time-axial (as it is shown in fig.3) to arrange the average linear relationship between the quantity of radionuclide and the time spent outdoors. Fig.3 shows the estimated

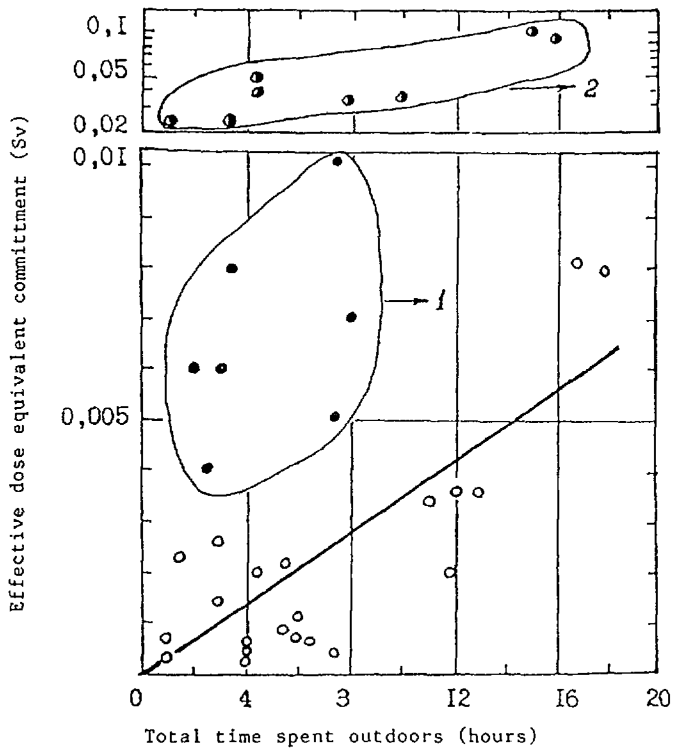

Fig. 3. Commitment equivalent beta-dose - total time spent outdoors curve.

individual effective equivalent beta-doses mainly formed by thyroid dose, multiplied by the standard weight factor of 0.03. In general these data are in satisfactory conformity with the above-discussed results of thyroid I-131 contamination measurements of 210 and 650 individuals respectively.

In assumption of the significant uptake of radionuclides by those who had their windows opened, protection factor (for 5 hours of 36 spent outdoors before the evacuation) may be considered to be about 3. On the other hand the explanation of this fact with the model of different radioactive streams, passing over the town during some periods of time is as trustworthy as the first one: According to this explanation all the experimental points in fig.3 should be considered as the uniform excerption; this is non-linear relationship between the accumulated dose and time spent outdoors; the actual inhalation uptake is caused by the individual reasons (interaction between individual and actual radioactive streams).

According to represented data about the content of alpha-emitters in feces the ratio of commitment equivalent alpha-and beta-doses (according to ICRP model) should be about 5-6 to 1 for lung tissue and 3000:1 - for lower colon.

More accurate assessments (for commitment alpha-beta-doses in skeleton particulary) could be made referring to alternative experimental data.

The trans-uranium elements were extracted from the urine samples of 82 individuals using the sedimentation method. Total alpha-activity of the samples was compared with the minimum detectible activity (MDA) in the twenty-four-hour quantity of urine (approximately 0.02 Bq/ 0.5 pCi). Content of trans-uranium radionuclides in 49 samples (60 % of examined) was less than MDA. Estimation of trans-uranium content in whole body at the day of measurement was conducted according to Langham model, dose calculation- according to ICRP lung model in assumption that the dispersion of aerosols was characterized with AMAD of 10 micron. The fraction of radioactivity, transferred from lungs to body liquids according to the results of aerosol particle dissolution test was assumed. Maximum content of trans-uranium elements in whole body was 780 Bq (21 nCi), average value - 100 Bq (2.7 nCi). Extrapolation of the data from the moment of analysis to the moment of the inhalation shows that average body content corresponds to inhalation of 1200 Bq (32 nCi) of trans-uranium elements in the form of aerosols with AMAD of 10 micron. Assessment of the commitment equivalent dose was conducted for the following trans-uranium nucline composition: Cm-242- 85%, Cm-244 - 2%, Am-241- 1%, Pu-239, Pu-240- 8.3% , Pu-238-3.2%. Pu-241 activity approximately 40 times exceeds total alpha-activity of the mentioned plutonium nuclides.

As a result of the estimation of alpha-dose caused by nuclides of Cm and Am it was ascertained that 80% of isotopes transfer from the intermediate chamber to bones and 10% - to liver. Plutonium isotopes distribution was assumed in accordance with ICRP Report 30.

Estimated values of the commitment equivalent alpha-dose for bone tissue for the above-presented inhalation uptake of 1200 Bq are as follows: 73 mSv (7.3 rem) for the first year after the inhalation, 310 mSv (31 rem) for first 10 year and 870 mSv (87 rem) - for 50 years. Red bone marrow dose is 12 times lower than bone tissue dose.

Strontium content in urine was determined for another group of 82 individuals using sedimentation method (Sr-89) and extraction method (Sr-90). Concentration of these nuclides in urine was approximately equal. For 37 individuals strontium content was less than the sensitivity threshold of the method (0.4 Bq/ 10 pCi per twenty-four-hours quantity of urine on Sr-89 and

Sr-90). Average content of the sum of noted isotopes of strontium in the organisms of the examined was about 740 Bq (20 nCi) and the maximum value - 2700 Bq (73 nCi). The represented average content corresponds to the commitmemt equivalent red bone marrow dose of about 0.3 mSv (0.03 rem) for 50 years. Compared with the contribution of the other factors of internal irradiation, this dose may, evidently, be neglected.

Average radionuclide content (for the group of 65 individuals) according to the results of examination on the whole-body spectrometer in May 1986 is given below.

In table 5 data about nuclide composition in bodies of those who died due to acute radiation sickness are presented.

Table 5. Radionuclide composition in the bodies of 65 examinated individuals

Nuclide	Nuclide content (kBq)	Related to Zr-95 content	The same for those who died of acute radiation sickness
Sr-89, Sr-90	0.74	0.13	0.14
Zr-95	4.1	1.0	I.0
Nb-95	3.7	0.9	1.0
Ru-I03	7.0	I.7	2.0
Ru-106	2.6	0.63	0.7
Cs-134	9.0	2.2	2.3
Cs-137	18.0	4.4	6.7
Ce-141	1.4	0.34	0.8
Ce-144	1.4	0.34	0.7
Trans-uranium elements	0.1	0.025	0.020

Comparison of the radionuclide composition (table 5) with the discussed results of fecal analysis leads to the conclusion of the relative body enrichment with Cs and Ru isotopes. During the estimations it was assumed that Cs isotopes belong to dissolution class D, the rest - to class Y. According to the lung model of ICRP, reconstruction of radionuclide inhalation uptake referring to its content, determined in May 1986 leads to rather close values of doses for various aerosol dispersions (AMAD 1-10 micron). The corresponding averaged assessment of the equivalent dose in human organs leads to the following results: for lungs - 21+-3 mSv (2.1 rem) for the first year and 30 +- 5 mSv (3.0 rem) for 50 years after the inhalation (the main contribution is from Ru-106 and Ce-144: 80-90%): for the whole body - 0.8 mSv (0.08 rem) for 50 years, 85% of this dose was accumulated during the first year.

Assumption of the fact, that all average assessments obtained from different groups may be combined, leads to the following characteristic of commitment inhalation irradiation of the " critical" organs for all adults evacuated from Prip`at (see table 6).

Table 6. Expected irradiation of the critical organs caused by inhalation uptake since the accident till the evacuation

Organ	Commitment equivalent organ dose, Sv / rem	
	1-st year	Half-century
Thyroid gland	0.14-021 / 14-21	0.14-021 / 14- 21
Lung tissue [x]	0.026 / 2.6	0.035 / 3.5
Whole body	0.00068 / 0.068	0.0008 / 0.08
Red bone marrow[xx]	0.0064 / 0.64	0.1 / IO
Bone tissue [xx]	0.073 / 7.3	0.87 / 87

Note: x Trans-uranium elements contribution into commitment equivalent dose is about 15%. ;

xx Mainly from trans-uranium elements.

It is noteworthy that assessments represented above were conducted for actually detected nuclides only and, excluding the thyroid dose, the short-livers contribution was not taken into consideration because of their total desintegration by the beginning of the monitoring. Evidently, the actual dose, accumulated first of all by respiratory organs should be overestimated. To conduct this assessment the knowledge of the actual short-livers composition is necessary. The total energy release of the nuclear fuel of RBMK-1000 reactor during the 6-15 days of sustain decreases 3 times (both for beta-particles and totally for beta-gamma-radiation). The same factor should be used for an upper assessment of a lung tissue dose.

Conclusions.

I. Internal irradiation caused by inhalation of the radionuclide mixture for all organs except bone tissue was accumulated during the first year after the accident.

2. The thyroid gland may be considered as a critical organ; average thyroid dose was about 1 MPD for professionals.

3. The trans-uranium elements make a main contribution to the commitment equivalent half-century dose in the bone tissue; the first year irradiation corresponds to their uptake about 0.25 MPI for professionals.

4. Though the estimative assessments were rather tolerant upon the possible variance of the inhaled radioactive aerosols dispersion, there are a lot of vague questions related to the role of other physico-chemical properties of the inhaled substances. These properties need experimental detailization under the modeled conditions of the radioactive releases, e.g. high temperature in accidental reactor.

SANITARY-DOSIMETRIC MONITORING OF FOOD PRODUCTS

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Abstract

Most of the monitoring measures implemented in the regions of greatest radioactive contamination were carried out for meat and milk products (36%) and water (45%). The efficiency of the control measures carried out during the first few months was estimated at 80-90%, and subsequently at 90-95%.

Radiation-related situation, arizing after the accident at the CNPP necessitated substantial extention and strengthening of the system of sanitary-radiation monitoring, which is usually carried out by bodies of the State Sanitary Inspection and also by special departmental services. As it is known, the cardinal task facing the bodies of sanitary-radiation monitoring is to avert human exposure, the level of which could exceed permissible sanitary standards. This task may be accomplished by systematic monitoring of radioactive contamination of environmental objects and foods, and should the necessity arise, by the control of radionuclide content in a human body. The character, structure, and scope of monitoring, as a rule, are dependent on specificity of a radiocontamination source, potential validity of various objects, influencing radionuclide intake by the human body. They are also affected by natural conditions, orientation of agricultural production, composition of diet and by other factors.

The system of State Sanitary Inspection (SSI) existing before the accident was a consequence of long-standing experience accumulated in supervising the radiation situation determined by global release of products of nuclear explosions and by radioactive wastes discharged into the environment by various enterprises. The SSI ensured operative and dynamic control of the environmental objects, since its activity was based on the extensive network of radiologic units of sanitary epidemiologic stations, that allowed not only to accomplish the principal task, i.e. to control exposure of residents, but also to reveal regional special features in arising radiological situation, as well as to assess significance of various routes and pathways of radionuclide intake of human body. All the above formed the basis for the model reflecting transfer of radionuclides in the environment before being ingested by the human body, with special reference to regional pecularities.

The accident at the CNPP proved a severe trial for the existing system of Gosagroprom (State agro-industrial complex). The accident led to a rather intensive radio-active contamination of large areas, not only surrounding the CNPP but of the distant ones as well. In the resultant situation it seemed likely that unecceptally high doses of radionuclides, primarily of iodine-^{131} and cesium-^{134} could be ingested by human body, including the uptake by food-chains. Though emergency decisions in the first post-accident period were made proceeding from the measured dose rate of external gamma-exposure, the monitoring of foods was initiated on the maximally possible scale. Two principal problems had to be solved here: the major one was to carry out sorting of food, and the second - to obtain data for correcting long-term prognosis of internal irradiation.

Food sorting was based on the Temporary Permissible Standards for radioactive contamination of foods, which were introduced according to accident-associated levels of population exposure, and subsequently the standards became more rigid.

Taking into account the season of the accident (early spring), the peculiarities of agriculture in contaminated regions, the focus of attention in the initial period was radiomonitoring of milk and greenery. Later the assortment of controlled food-stuffs widened and finally covered the whole set of local products. The first task - food quality control - was provided by the measurements of the sum of beta-activity of all the samples. With the purpose of obtaining trustworthy and unified mass estimations of volume and specific activity of water and food-stuffs, the all-union express-method of direct measurement of beta-emitting nuclides in "thin-leyer" sourse was developed. The method was oriented on the existing in our country stock of serial radiometric instruments and allowed to conduct radiation control of food-stuffs with the contamination exceeding $5 \cdot 10^{-9}$ Ci/kg, and for water - $1 \cdot 10^{-10}$ Ci/kg without sample concentration (evaporation, ashing, etc.). The method took into account the average real composition of nuclides in the measured samples, characteristic for the concrete period. Together with alterations in radionuclide composition the correction of instrument counting coeffitients was conducted. The used means of measurement were checked in the system of the USSR Gosstandard, and the involved personnel was trained on the base of radiological departments of sanitary-epidemiological stations and veterinary service. All these organisational and methodical measures allowed to efficiently unfold the reliable system of radiation control of food-stuffs by practical establishments of the Ministry of Public health of the USSR and of the Union republics, along with establishments of the State agro-industrial complex and other departmental services.

In addition, the samples were analyzed by spectrometry and radiochemical assays to determine a spectrum of radionuclides, to reveal regularities in ingestion of individual nuclides via food chains by human body, and also to have ancillary control of quality of radiometric screening and, should the necessity arise, to correct the expert estimates. Major radionuclides causing internal irradiation in the first post-accident period were ^{131}I and radionuclides of cesium. Later, the level of radioactive contamination of foods was reduced both due to decay of short-lived radionuclides and owing to altered predominant pathway of contamination, since the superficial pathway was replaced with the soil one, which by the end of I986, and, particularly in I987 practically completely determined the content of radionuclides in local agricultural produce. The data of spectrometry showed that by the middle of I987, radioactive contamination of food entirely depended on ^{137}Cs and partially, on ^{134}Cs. In view of the above, the most recent Temporary Standards of food contamination are oriented solely towards radionuclides of cesium. Under these conditions the role of spectrometric and radiochemical methods of control became more important since they proved not only more accurate techniques but also provided data for correcting long-term prognosis in case of internal irradiation.

Table I presents the scope of radiometric studies of principal foods and water in I986-I987, conducted on the territory of Byelorussian SSR by the Ministry of Health. It should be mentioned here that the control was focused on the areas with the most intensive radioactive contamination. For this reason, the samples, which values exceeded the levels of permissible radiocontamination of foods, cannot be regarded as a mean indicator for the entire volume of agricultural produce in the republic. Information of Table I demonstrates, that radiation monitoring covered all the

Table I. Quanity of radiomonitoring of food stuffs and water in Byelorussian SSR in I986-I987

	Milk	Milk products	Meat and meat products	Vegetables	Fruit	Grain, bread	Other	Water	Total
Total	3327I8	II5225	I24988	89374	37838	34970	I47453	799048	I6II6I4
Exceeding permissible levels	43302	6438	I0235	6282	I3I5	806	I2I04	8760	89342
%	I3	5,6	8,2	7,0	3,5	2,3	8,2	I,2	5,5

regions where the levels of radioactive contamination could, probably, be exceeded, as well as the adjacent areas. The bulk of radiation control was focused on meatdairy products (36%) and water (45%).

Systematic control of local agricultural produce both in public and private sectors provided the possibility to specify those populated areas and farms, where radiocontamination of some kinds of products (primarily, of meat and dairy products) exceeds the permissible levels. Depending on the degree of radiocontamination, the decisions were made whether to impose a ban on the consumption of given products, or to process this batch of food into some other kinds (whole milk into butter and other dairy products). Furthermore, there was devised a complex of organizational and agrotechnical measures aimed at reducing the level of radionuclides to the permissible value.

Informational and sanitary educational work of radiologists and hygienists among different sectors of population and economic executives proved an important element in the system of radiation monitoring.

The entire complex of measures implemented to control radioactive contamination of foods, promoted sharp decrease in significance of peroral intake of radionuclides, (including the major ones ^{131}I and radioisotopes of cesium), in formation of dose burdens for population. Effectiveness of the steps taken within the first months may be evaluated as 80-90 %, and in the subsequent period it reached 90-95 %. The estimates presented are based on the direct measurements of radionuclide content in foods, human body, on the lacking correlation for overwhelming majority of residents who followed restrictive measures, between radionuclide level in the body and density of territorial radiocontamination.

The matetial of sanitary-dosimetric monitoring, accumulated within the post-accident period, allows characterization of dynamic changes in radioactive contamination of foods, with the view of being able to further perfect and optimize the service of control. Specifically, the level of radioactive contamination of livestock products (milk, meat) remains rather high, and for this reason the scope of control over these products is not to be modified in the nearest future. At the same time, the level of radioactive contamination of grain crops, vegetables, nearly in all the areas failes to reach the standardized values, and thus it seems expedient to raise the issue of reducing the volume of radioactive monitoring with subsequent transition to random checking. In view of the above the radiation monitoring service should be equipped with gamma-spectrometric instruments on a large-scale.

RADIATION MONITORING OF VARIOUS OBJECTS AS PART OF THE CHERNOBYL ACCIDENT MANAGEMENT PROGRAMME

O.A. KOCHETKOV, D.S. GOL'DSHTEJN, D.P. OSANOV

Abstract

Permissible levels of radioactive contamination were based primarily on an experimentally established relationship for contamination in the region around the Chernobyl power plant: the gamma exposure dose rate measured close to a contaminated flat surface, 1 mR/h, is equivalent to 10 000 beta particles/cm^2•min. From this relationship, it follows that the established contamination limit of 0.1 mR/h roughly corresponds to the limit for contamination of the outer protective clothing worn by staff at nuclear power plants as laid down in the radiation safety standards (NRB-76), namely 800 beta particles/cm^2•min.

Experience in establishing radioactive contamination standards and in organizing radiation monitoring made it possible to reduce significantly the adverse effects of the accident.

The accident at the nuclear power plant led to radioactive contamination of environmental objects on extensive areas of Kiev, Mogilev, Gomel and some other regions, particularly within the 30 km zone of the Chernobyl NPP. This necessiated organization of large-scale radiation monitoring of contaminated roads, buildings, transport facilities, articles of daily use, clothes, and human integument etc., in order to prevent or to reduce substantially transmission of contaminating radioactive substances into the areas adjacent to the CNPP, and, therefore to obviate additional exposure of residents.

To carry out radiation monitoring on such a large scale it was mandatory, in the first place, to introduce safety standards, which had to be realistic for the arising situation, and also to deploy sufficient amount of radiometric equipment, solving at the same time numerous organizational problems. The situation was complicated by the fact, that under the above conditions it appeared impossible to utilize the permissible levels of radioactive contaminations for surfaces of various objects, working clothes, additional individual means of protection, specified by SRS-76. Primarily, it was necessary to go over from the existing SRS-76 where permissible levels of contamination were calculated at a number of beta-particles on I cm^2/I min to estimating the dose rate of gamma-radiation from the surveyed objects. The latter, was mostly governed by the following considerations:

- dose rate of gamma-radiation could be measured much faster compared to estimating radiactive contamination in particles (cm^2/min);
- measurement of radioactive contamination in beta-particles (cm^2/min) in the event of augmented gamma-background appeared rather difficult;
- the amount of instruments for measuring radioactive contamination of various objects in beta-particles (cm^2/min) was insufficient.

It should be noted here, that SRS-76, like similar documents in other countries, failed to specify such standards for majority of objects, exposed to radioactive contamination specifically for clothes of residents, articles of daily use, surfaces of buildings, roads, transport facilities, etc.

At the same time, radiation hygiene has already accumulated sufficient experience and knowledge, that enabled the experts from the Institute of Biophysics uhder the Ministry of Public Health of the USSR to elaborate promptly in the very first days after the accident the "Temporary Permissible Levels of Radiation Contamination for various objects" which were approved by the Chief State Sanitary Doctor of the USSR on the 7th of May 1986 (see Table 1).

Table I

Temporary permissible levels of radioactive contamination for various objects

Contaminated objects	Rate of exposure dose of gamma-radiation, mR/hr
Integuments, underwear, towels, bed-clothes, clothes, footwear, individual means of protection	0.I
Surfaces of buildings, internal surfaces of transport facilities	0.2
Outer surfaces of transport facilities	0.3

While defining the permissible levels of radioactive contamination presented in the Table 1, as a basis, there was taken experimentally determined relationship of radioactive contamination in the area of CNPP, where the exposure dose rates of gamma-radiation I mR/h, measured in the vicinity of contaminated surface correspond to the specified by the SRS-76 values of permissible contamination of CNPP personal working overalls equalling 800 beta-particles (cm^2/min). This value of permissible level established by the SRS-76 implies 30 year length of service for the personnel.

Furthermore, it had to be born in mind that the specified by SRS-76 permissible level of 100 beta-particles (cm^2/min) for density of skin radiocontamination was established on the basis of radiobiologic studies taking into account both direct irradiation of the skin basal layer by the substances deposited on it, and also the portion of radioactive contamination penetrating the skin. If length of exposure to radioactive nuclides equals 1700 hr per year, then the above standards have for principal fission products except ^{90} Sr, ^{90} Y not less than 10 fold reserve, and for ^{137}Cs it is even 30 fold. For Sr^{90} and ^{90}Y, this reserve amounts only to 2-3 times, but their percentage in the composition of contamination substances was rather amall.

Therefore, it was warranted to implement temporarily, for the period of elimination of the accident consequences, the levels of permissible contamination, presented in the table. On the whole, this document provided the legal basis for preventing the transfer of radioactive contamination from the zone, where the work was carried out on elimination of the accident consequences. Parallel to this, the established values of permissible contamination levels were utilized as a principal criterion in assessing the effectiveness of large-scale decontamination works. Particular attention was given to the control of radioactive contamination of transport both leaving the 30 km zone of the CNPP, and also when it entered all large cities of the European part of the USSR.

The tadiation monitoring was carried out besides the military personnel of the Soviet Army by the units of civil defense, with active participation of researchers and under-graduate students from the institutes with suitable orientation. The stations of radiation monitoring organized on the roads worked together with the posts of State Traffic Inspection. Moreover, if the necessity arose, additional control stations were set up.

In addition to radiation monitoring on the roads, the radiation control was organized on a large scale in populated areas which were affected by radioactive contamination apreading from the zone of CNPP.

Radiation monitoring in the populated areas was instituted on the basis of local bodies of sanitary inspection together with territorial organs of civil defense, which received large scientific and methodological assistance from corresponding republican and All-Union bodies as well as from research institutions. Proceeding from the results of the all-over radiation monitoring, the decisions were made whether or not the residents of inhabited areas could stay in the settlements located in the vicinity of the CNPP 30 km zone. In those cases when it was deemed safe to allow population to stay in their homes, new regulations were introduced governing the every-day life of residents. Special attention was paid to systematic control of food and water contamination. The results of radiation monitoring served as a basis for taking necessary sanitary-hygienic measures in all regions with increased levels of radioactive contamination. Implementation of the planned measures was strictly supervised by local authorities and, particularly by the bodies of the State Sanitary Inspection.

Within the 30 km zone of CNPP the radiation monitoring was conducted primarily by military personnel, participating in elimination of the accident consequences, and also by researchers from the Institute of Biophysics under Ministry of Public Health of the USSR as well as by experts from some other research institutes. The radiation control in the zone of CNPP was in addition, carried out by the radiation monitoring service, reinforced substantially by specialists who volunteered from other NPP. In this zone, major attention was given to training of personnel, engaged in mitigation of the accident consequences. It is noteworthy to mention, that in different areas within the 30 km zone of CNPP, differntiated permissible levels of contamination were established depending on radiological situation, character and time of concrete works performed to eliminate the accident consequences, and also taking into account how the personnel used the individual means of protection. Thus, for instance, when the work was conducted directly on the construction site of the CNPP in May-June of 1986, and the rate of exposure dose of gamma-radiation reached dozens and hundreds mR/hr, it seemed unwarranted to limit the permissible levels of radioactive contamination for working clothes and individual means of protection by the value of 0.I mR/hr. For these reasons the decision was made to establish the value of 5 mR/hr as a permissible level of radiocontamination for overalls if the work was conducted under the above conditions.

In the course of radiation situation being normalized, the permissible levels of contamination for various objects were repeatedly revised and made more rigid, gradually approaching the values of SRS-76. Specifically, on completing the construction of the sarcophagus, having carried out the major part of decontamination works, and restarting the first and second power units at the CNPP it became possible to return in the premises of power units to the standards of radiocontamination for surfaces established by SRS-76 in beta-particles (cm^2/min). And at the border of the CNPP 30 km zone the permissible levels of radioactive contamination for working clothes corresponded to the levels specified by the SRR-76 for the integument of personnel.

In general, the experience gained in standardizing radioactive contamination and also in organizing radiation monitoring while eliminating the consequences of the CNPP accident, shows that even in the event of such a large-scale accident at the NPP, the scientifically substantiated measures, taken in time, provided the possibility to prevent transfer of radioactive substances by clothes, transport facilities and other objects beyond the limits of 30 km zone. Due to the above measures, the risk of radiocontamination of humans, their property and houses was substantially reduced, and all that, together with various sanitary-hygienic actions contributed to sharp decrease of the accident negative consequences.

PERSONNEL PROTECTION DURING A REACTOR ACCIDENT

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Abstract

In organizing individual protection and the provision of protective clothing and equipment for accident teams, particular attention must be paid to protection of the respiratory organs. A system of disciplinary barriers, personnel airlocks and gates and transport processing points - with obligatory monitoring of all movements of staff and equipment - is described.

Individual protection of man is a unified system of social, technical, medical and organizational-and-psychological measures aimed at ensuring vital activity, as well as shaping and maintaining the professional adaptation of man to labour activity under adverse circumstances. In an emergency, this system acquires a special significance.

The radiation situation, which arose as a result of the accident at the Chernobyl Nuclear Power Station (CNPS) and the resulting necessity of enlisting help of large number of the station's staff and the Soviet Army personnel with a view to eliminating its aftermath, called for taking a package of measures to ensure individual protection. These measures had the following for an object:

- to exclude or reduce to permissible levels the radioactive contamination of skin and, which is most important, the intake of radioactive substances through the respiratory organs with due account of the radiation situation and the nature of work aimed at eliminating the accident's aftermath;
- to prevent the spread of radioactive substances through contaminated working clothes and special footwear;
- to ensure timely cleaning of working clothes and other means of individual protection (MIP), contaminated with radioactive substances, to the established permissible levels;

- to evaluate service and hygienic properties of prospective MIP with a view to solving matters of the advisability of their putting into practice;
- to ensure individual protection of the population residing in areas with increased levels of radioactive contamination;
- to conduct sanitary-and-educational work dealing with various aspects of radiation safety and application of means of individual protection, etc.

Naturally, individual protection of the personnel under conditions of elimination of the aftermath of an accident of a scope such as that which occurred at the CNPS has its own peculiarities, distinct from the work which is conducted at nuclear stations under normal conditions and during repair. On the whole, the following is characteristic of emergency situations, irrespective of their specific features:

- high intensity of unfavourable effects;
- the necessity of carrying out important and complex jobs when there is a shortage of time;
- ultimate physical and psychophysiological exertion of the working personnel;
- the necessity of providing the NPS personnel with means of individual protection and organization of their use with a great number of personnel.

In the course of elimination of the aftermath of the accident at the CNPS, carried out on the basis of a thorough analysis of the situation, a set of standards and procedures was worked out and largely implemented. These documents specified individual protection of the personnel and population. Besides, new means of protection were introduced, with high protective and service properties and minimal loads acting upon the human body.

Particular emphasis was placed on the testing and putting to use of self-contained filtering MIP with air blow - the most effective and promising type of means of individual protection as far as human activity in emergencies is concerned. The use of means of individual protection, such as the special protective gear for welders and insulating suits of КЗМ type, yielded good results. Apart from that, put to the test at the CNPS were the service properties of expendable working clothes made of non-wolen heat-resistant material, suits equipped with self-contained cooling systems, etc.

The introduction of a system of sanitary-checking routine was an important element of the individual protection of the personnel and prevention of the spread of contaminants. A rigorous system of barriers, sanitary "sluice gates" and check points, vehicles- treatment stations with compulsory control over the transport of people and equipment was introduced.

Radioactive decontamination of working clothes, footwear, means of individual protection, uniform, etc. is of paramount importance in the system of individual protection. It was established that in the case of a radioactive discharge contaminants stick to working clothes much more firmly than under normal conditions or during repair at nuclear power stations, and it is much more difficult to cleanse working clothes of such substances. This may be explained by the basically different nature of contamination which resulted from the discharge of radioactive substances from the fourth power generating unit. A decontamination routine was worked out, based on the redox method, which largely settled the problems connected with the decontamination of MIP.

The question of protection of the personnel from penetrating radiation should be discussed in more detail. As shown by the testing of a suit provided with a lead shielding, in case of one-way radiation with the energy exceeding 120KeV, the attenuation ratio is $1.1 \div 1.4$. In case of arduous jobs involving movement of workers, the duration of wearing such an outfit is reduced by 15-20 percent as compared with organic clothing. At the same time, the exercise stress abruptly rises due to the increased weight of this outfit - 20 kg (with 11 kg being the normal weight). To ensure reliable protection of personnel from penetrating radiation with such intensity as that taking place at nuclear power stations, one has to use a protective outfit weighing more than 200 kg. In other words, the protection of personnel against penetrating radiation is just a matter of time.

The problem of psychophysiological selection of personnel for work under marginal conditions is prominent among the problems of ensuring medical protection during elimination of major accidents. Questions of staffing nuclear power stations with operating personnel, whose mental state and professionally significant psychophysiological qualities enable them to reliably and efficiently perform their duties under distress conditions, should be tackled along with matters of functional rehabilitation aimed at achieving a high level of general and professional working capacity.

The experience, gained in the course of elimination of the aftermath of the accident at the CNPS, urgently demands that a package of measures be worked out with a view to ensuring reliable individual protection of the personnel of the nuclear power station and population living in its vicinity in case of an accident at a nuclear reactor. In working out these measures, a differentiated approach must be taken to the problem of protection of four categories of people. These are:

Firstly, emergency teams from among the nuclear power station's personnel, which will be directly involved in tackling problems of the elimination and localization of an accident, should one occur;

Secondly, medical personnel rendering aid to victims of an accident;

And, finally, the population residing in proximity to the nuclear power station, which in some way or other is exposed or may be exposed to the effect of radioactive discharges.

A scientifically substantiated set of means of individual protection should be recommended for each of the above categories. Full and effective realization of these recommendations will require a physiological-and-hygienic substantiation and, besides, emergency protective means. Specifically, there will be a need for unified MIP kits to be used for arduous emergency jobs; quantity production of prospective MIP, including the self-contained filtering MIP with air blow; general-purpose front parts of MIP which would not restrict the viewing angle; expendable working clothes made of non-woven material, etc.

In organizing the individual protection and packing up protective means for emergency teams, particular attention should be given to protection of the respiratory organs. In emergencies, it is advantageous to use either the PM-2 respirator, which ensures protection against radioactive aerosols and gaseous iodine, or the ГР-7 filtering protective mask with canisters fitted with anti-aerosol filters and the panoramic mask of ППМ-80 type.

In view of the potential danger of catching fire by equipment and resulting high smoke content in rooms, the MIP emergency kits have to be furnished with insulating respirators (КИП-8 or РВЛ-1) and a set of heat-resistant clothing for firemen (TK-800). Special emphasis should be put on the protection of skin. The emergency kits should contain a set of film MIP, insulating suits made of PVC film or rubberized fabric, as well as hose protection means coupled with self-contained sources of air supply (АИВ-1, АИВ-3).

With a view to protecting the personnel which is to be evacuated from the hazard zone, besides the main working clothes and special footwear (or personal clothing of the personnel working within the free-access zone), use should be made of other means of individual protection, such as general-purpose respirators of PM-2, "Lepestok-A" or "Lepestok-Apan" type, a protective film cape with a hood, special footwear and rubber gloves. Along with this, the ШС -7M mine-type survival pack should be provided in case there is a need for evacuation from a smoke-screened area.

Unlike the evacuation kit for the station personnel, the MIP kit for medical workers should also include body linen, cotton working clothes and a film semi-cloak with a hood (instead of the cape).

For better safety of the population to be evacuated from areas in the vicinity of the station, a unified MIP packing case has been proposed. A principle of domestic storage of these means has to be developed.

Besides, the long-term measures, aimed at improving the system of individual protection, should also include the development of technical training aids and equipment for exercising control over work in marginal conditions with the use of MIP. For this purpose, there is a need for a series of teaching aids (films, lectures, instructional wall sheets, etc.) and training centers where the personnel could be taught directions for use of the means of individual protection under actual-use conditions.

PROTECTIVE MEASURES TO REDUCE POPULATION EXPOSURE DOSES AND EFFECTIVENESS OF THESE MEASURES

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Abstract

Basic measures to protect the population from radiation after the Chernobyl accident included: (i) monitoring of radiation conditions and exposure doses to the population; (ii) temporary or permanent evacuation of certain population groups; (iii) iodine prophylaxis; (iv) limitation of the intake of radionuclides with food products; (v) decontamination of land and buildings; and (vi) educational work and sanitary instructions to the population.

More than 5 000 000 measurements were carried out on different objects. In some population centres external doses exceeded level A, reaching 0.3-0.4 Gy, but nowhere did they reach the upper level B. More than 70 000 farms were decontaminated and a total of about 200 000 m^3 of contaminated soil was removed from large areas, taken away and buried. In 1987, as a result of these effective measures, the contribution to the dose from internal exposure averaged only 10-30%.

The overall effectiveness of the protection of the population living in the zones of radioactive contamination can be expressed in terms of the conservation of 7000 man-years of normal life.

As a result of the accidental releases of radioactive products from the reactor unit 4 of the Chernobyl plant, a large territory of the country (not only the regions closely adjacent to the place of accident but also those removed from it by hundreds and even thousands of kilometers) have been exposed to radiation. The central part of Ukraine, the south-eastern regions of Byelorussia and some regions of the European part of the RSFSR adjacent to the place of accident have been most heavily exposed. The general number of population living within the above mentioned territories makes 17.5 million, including 2.5 million of children younger than 7 years old.

The situation arisen required an urgent development and realization of a number of organizational, radiation-hygienic, medical-biological, agrotechnical and other measures. In addition to the measures for immediate protection of the population living in the towns of Prypyat' and Chernobyl and at the 30 km zone around the plant, it was necessary to solve complex and diverse problems of protecting the population living at large territories with the increased radiation contamination levels. Such large-scale tasks on radiation protection of the population were being solved for the first time in the world.

The purpose of the present paper is to give a general characteristics to the principal measures for decreasing radiation doses to the population taken in the course of eliminating the consequences of the Chernobyl accident and to estimate their efficiency.

The complex of principal measures of radiation protection included:

1. Control of the radiation situation and radiation doses to the population.

2. Temporary or permanent evacuation of the population and removal of some of its groups for summer health-improving rest.

3. Iodine prophylaxis.

4. Restriction of radionuclide intake with food.

5. Decontamination work.

6. Careful medical examination of the population exposed.

7. Explanatory and sanitary-educational work.

The possibility to create such conditions of life and activities for the population at the contaminated territories which would help to restrict the radiation doses within the established dose limits: of 0.I Gy for the first year and 0.03 Gy for the second year after the accident survved as efficiency criteria of the measures performed.

As it is known, radioactive products were being released from the damaged unit for a long time. It occurred at different meteorological conditions the most important of which (for the formation of a radiation situation at particular territories) were wind direction and velocity and also availability or unavailability of precipitations at the route of air mass movement transferring radioactive products.

The main factors which determined radiation exposure were: external gamma radiation of the cloud and of the radioactive fallout; intake of radionuclides with inhaled air and, mostly for iodine and cesium isotopes, with food of the local origin.

These factors vary in their character, duration and intensity.

Gamma radiation of the radioactive cloud and fallout creates the dose of external radiation. The contribution from radiation of the cloud into the total dose of gamma radiation for the first year after the accident was about 10 per cent, with 90 per cent from the radioactive fallout.

The isotopes of iodine, penetrating the human body first of all with contaminated milk, concentrate in the thyroid, relatively small in mass, and create there a significant dose of internal radiation. In 2.5 months after the accident this factor due to decay of iodine-131 practically lost its significance.

It was a "cesium" factor that became the most long-term and determined internal human irradiation. Being an analogue of potassium cesium enters potassium metabolic chains and thus accumulates in the human body. Cesium enters the body by the same routes as potassium. The main sources of a radiocesium intake into the body are milk and meat. After entering the body cesium as well as potassium uniformly distributes in the soft tissues.

Contrary to the first two radiation factors, i.e. external gamma-radiation and radioiodine cesium dose not act instantly. Cesium has a certain accumulation period in the body which depends of the person's age. If a man constantly consumps food containing radioactive cesium its balance in the body can be achieved at the following time periods: for a child of on year - in 1.5-2 months, for a 10 year child - in 4 months and for adults - in half a year or more. Elimination of cesium from the body has the same rate as its accumulation. Elimination rate in children exceeds that in adults. Thus, averagly elimination half-life of the accumulated cesium will be: 17 days for a child of one year, 40 days for a 10 year child and 60-100 days for adults of 25-60 years old.

The surveillance system operating before the accident could not provide a timely assessment of the radiation situation aroused by reason of the greatly increased amount of measurements required and the objects requiring control, shortage of measuring devices and very uneven character of contamination. In these emergency conditions the necessary forces of the Ministry of Health of the USSR, of the Academy of Sciences of the USSR of the Ministry of Defence of the USSR, of the State Committee of Hydrometheorology and of other organizations were thrown to participate in medical, ecological-hygienic and radiometric examinations and measurements beginning from the first days after the accident. The most contaminated regions were fixed to the leading medical organizations.

Technical equipment of the field teams consisting of physicists, dosimetrists, radiochemicists, hygienic workers, radiologists and others made it possible for them to carry out at the populated areas the estimations of gamma radiation levels and radiation contamination to make a detailed analysis of radionuclide composition of the contaminated environmental objects and food-stuffs, to measure a radioactive content in the human body and also to estimate the condition of human health.

Totally at this stage of work more than 3 millions of measurements have been made for the purpose of obtaining a true picture of radioactive contamination in various objects (air, water, food, soil, vegetation, etc.), the content of incorporated radionuclides in the human body and the doses of external irradiation.

A prompt collection and analysis of data about the radiation situation at the contaminated territories and a direct control of external and internal irradiation made it possible to form without delay a true nation of the radiation situation aroused and reliably predict future development of events. That in its turn gave the possibility to realize substantially and in a due time various protective measures including making decisions about evacuation of the population from this or that location in the affected area.

At the stage of evacuation an important role belonged to the "Criteria for making decisions about measures taken for protection of the population in case of a reactor accident" which were developped and adopted in 1983, i.e. long before the events considered here. The use of these "Criteria" proceeded from the consideration that protection of the population from external irradiation and inhalation intake of radionuclides at the time when a cloud of the accidental release was passing over required the most urgent measures. The measures of preventing consumption of milk contaminated by levels of radioactivity exceeding the permissible standard were less urgent.

The experience aquired from the Chernobyl accident demonstrated a working capacity of the above mentioned "Criteria" which established two levels of irradiation, A and B (0.25 and 0.75 Gy, respectively) comparable to the recommentdations by ICRP, WHO and IAEA. The dose values of external irradiation exceeded the level "A" and made up 0.3-0.4 Gy only at some small populated localities but they never achieved the values corresponding to the higher level "B".

The wide range of contamination levels forced the use of a zone making conception necessary for development of the system of radiation safety. The zones which have been marked included: a 30 km zone later transformed into a zone of evacuation, a zone of control with the threshold values of contamination density for plutonium-239, strontium-90 and cesium-137 0.1; 3.0 and 1.5 Ci/km^2, respectively and regions exposed to lower levels of contamination. The areas with contamination densities by plutonium-239 and strontium-90 higher than the established thresholds were within the 30-km zone from which as it is known the population was evacuated. Large territories with an increased contamination density by radiocesium were outside the 30-km zone. Located at these territories were about 600 populated areas where people continued to live but lived in the conditions of a rigid control over food-stuffs of the local origin up to their withdrawe and replacement by clean food imported from other regions of the country. These territories were called zones of a rigid control. The number of evacuated localities from the zone of evacuation was 185 with the total population of 135 000 including the town of Prypyat'.

For the sake of prophylaxis all the children and pregnant women who lived at the 30-km zone and in other regions of the Ukraine, Byelorussia and the Russian Federation exposed to increased radiation levels were directed by centralized order to summer health resorts in 1986 and in 1987. Temporary removal of children and pregnant women helped significantly to decrease the radiation effects on these critical population groups. It was especially important in the first year after the accident when the doses of external gamma irradiation rapidly increased. For the sake of illustrating the range of this measure it should be noted that the total number of children and pregnant women removed for summer health rest in 1986 in the Ukraine and Byelorussia alone made up to 174 000 individuals.

As one of the protective measures iodine prophylaxis played an important role in the first year after the accident, especially for children. Effeciency of this measure realized by the use of stable iodine, for example in the form of potassium iodide pills essentially depended on the time of radioiodine intake into the human body with the inhaled air or foodstuffs. If iodine prophylaxis of the population and especially of young children (of three and less years old) was performed within the first 3-5 days from the beginning of consumption of the contaminated food then even in spite of the continuous intake of radioiodine with diet its content in the thyroid was minimum and the absorbed dose was within 0.1-0.2 and 0.03-0.05Sv in children and adults, respectively. If iodine prophylaxis was performed later (on May IO-I5) its effeciency was significantly lower. As a whole, iodine prophylaxis performed at earlier time (for the first 3-5 days) provided a decrease of the absorbed doses in the thyroid averagely by IO times and later (in IO-I5 days) - by 3-4 times.

This is especially true of the children living at the 30-km zone and in Prypyat' as they received iodine for prophylaxis by the centralized order and at the earliest time. Direct measurements of radioiodine content in the thyroid in this population group showed that the absorbed doses of internal irradiation of the thyroid did not exceed 0.03 Sv.

The base of restricting radionuclide intake into the human body was laid by an introduction of the temporary guidelines for their permissible content in the foodstuffs. The guidelines were developed for those radionuclides and media which at a given stage of bringing the consequences of the accident under control determined human irradiation. Thus, immediately after the accident the guidelines of permissible content of iodine-131 in milk, milk products and in leafy vegetables have been introduced. These guidelines supposed that the radiation dose to the thyroid in children would not exceed 0.3 Gy. In addition the temporary guidelines of permissible content of iodine-131 in meat, poultry, eggs berries and drug materials have been introduced. The guidelines operating earlier were supposed to restrict radioiodine intake into the human body. The guidelines adopted on May 30 1986 regulated a permissible content of cesium radionuclides in food, water and other media. These guidelines were supposed to proceed from the fact that at any set of foodstuffs the maximum dose of internal irradiation would not exceed 0.05Sv per year.

During the first period following the accident when the main doseforming radionuclide of internal irradiation was iodine-131 its principal "supplier" into the human body, especially into that of children was milk and to a lesser degree - fresh leafy vegetables (sorrel, lettuce, spring onions, etc). The content of iodine-131 in milk was within the range of hundreds - thousand hundreds Bq/l and in a half of cases the specific activity of milk was 37 kBq/l. At the same time the maximum permissible content of iodine-131 in milk which provided unexceeding of the dose to the thyroid (0.3 Sv) according to the introduced guidelines was 3,7 kBq/l. Therefore the measures directed at a decrease of radiation doses to the thyroid from radioiodine together with mass iodine prophylaxis included a constant radiometric control and in case of exceeding the guidelines a rejection of agricultural products and their direction to special treatment.

An active measure used for a decrease or even exclusion of radioactive intake into the human body was transfer of the population and first of all children to the consumption of food-stuffs of agricultural origin imported from other regions of the country.

When milk contaminated by radioiodine to the extent exceeding the temporary permissible levels was processed to butter, cheese or soft cheese the level of their radioactivity decreased by 2.5-3 times compared to the original product. Treatment of milk was also continued latter to prevent an intake into the human body of significant amounts of radio-cesium. In this case an elimination effect was 98, 90 and 75 per cent when milk was processed into butter, cheese and soft cheese, respectively. With the account of mean daily consumption of these products by man which is by 3-5 times less than that of milk a decrease of radioiodine intake was up to 8-15 and of radiocesium - by 4-50 times.

A subsequent period when the main radiation dose of internal irradiation was formed by radiocesium and its leading intake was as before determined by milk and meat radiometrical control and if necessary rejection of these products were increased. To exclude an intake of cesium radio-nuclides into the human body in the amounts higher than the established ones a planned cattle slaughter was prohibited and beginning from the autumn of 1987 the cattle before slaughter was transferred for 1-1,5 months to the clean ration. During 1986-1987 the population living at the zones of rigid control as a rule was fed a died consisting of milk and meat products imported from other regions of the country.

Due to the rapid accumulation of radiocesium in fish from stagnant ponds, in mishrooms and wild berries these products were subjected to an obligatory dosimetric control.

Agrotechnical and reclamation measures carried out at the affected territories by the Gosagroprom have been actively used for decreasing the probability of biologically harmful radionuclides getting into the human body through the food chains and thus for lowering dose burdens to the population. These measures included: insertion of mineral fertilizers in sufficient amounts (especially potash fertilizers) soil liming, deep ploughing with overturning the upper layer, use of cultivated and reclamated pastures for cattle beeding, change of the type of agriculture and if necessary change of land tenure.

In July 1986 methods for calculating the levels of external and internal irradiation of the population living at the territories affected by the accidental releases from Chernobyl were developed. These methods together with experimental data on radiation parameters have been used as a base for recommendations of returning children and pregnant women to the places of their permanent residence, additional evacuation of the population from the localities where it was impossible to provide by other means unexceeding of the established (for 1 year) dose oimit of 0.1 Gy and choice of places for building temporary and permanent settlements.

To decrease external gamma irradiation a wide range of decontamination work has been carried out at the contaminated territories. According to the Ministry of Defence which fulfilled the main work decontamination measures were taken at the area of about 7000 km^2. More than 600 populated localities have been decontaminated and about half of them repeatedly (in order to achieve a maximum decrease of the contamination levels). During decontamination the most attention was paid to social buildings (schools, nursery schools, etc). Buildings which after triple treatment were not decontaminated to the permissible standards and also contaminated ramshackle buildings of low value were disassembled and buried. More than 70 000 homesteads were predecontaminated, contaminated soil was removed from large territories, and about 200 000 m^3 of soil was taken away and buried. Much decontamination work was done on the roads and at the roadside areas: decontamination of surfacing (more than 25 000 km) and dust fastening along the area of 43 000 km. Dust suppression was made at the total area of more than 50 km^2.

Asphalting and covering the contaminated areas with gravel, broken stone, sand or clean soil made it possible to achieve a decrease of gamma radiation dose rate by about 10 times. Decontamination of homesteads was made by cutting off the upper layer of soil down to 10-15 cm. This measure led to a decrease of gamma radiation dose rate by 3-4 times.

Decontamination of roads with hard surfacing by daily mechanized washing decreased the levels of radioactive contamination by about 2 times. Natural-soil roads were gradered down to 10 cm , they were also asphalted, concreted and covered with broken stones. As a result a decrease of their radioactive contamination was about three-fold.

Explanatory and sanitary-educational work was an important part in the complex of measures directed at normalizing the moral situation at the affected territories. The aim of this work was to give the objective and timely information to the population about the local radiation situation, about the main factors determining the situation and about potential risk of registered and predicted levels of human irradiation, especially irradiation of pregnant women and children. The leading soviet scientists and experts spoke before the people explaining them all necessary recommendations directed at the maximum decrease of radiation factors. All the questions received competent and comprehensive answers. As far as it was possible all mass information means have been used for its explanatory work; the press, radio and TV. Their task was to exclude any attempt of minimizing the risk from one hand and not to exaggerate it from the other. In the latter case it could lead (and unfortunately sometimes it did) either to the lack of confidence in the information which was supplied or to stress with all the subsequent inadequate responses, such as panic (for example, urgent departure for a long time with children to other regions, refusal to use foodstuffs even of proven reliability; sometimes abortions, etc.). But along with this it should be emphasized that the majority of the population did not leave the places of their permanent residence and as a whole maintained the place.

Experience obtained from this explanatory work demonstrates that the population quietly appreciated the situation in the majority of localities where the necessary explanatory work had been conducted by competent experts from the first days after the accident and the number of neurotic responses was not increased.

Thus, the control of radiophobia (fear of irradiation) is one of the most important links in the whole complex of protective measures. It can be put even more definitely: harm to health from radiophobia sometimes (fortunately not often) was dear and essential compared to the negligible and mainly undetected possibility of any late effects of irradiation.

This paper did not set itself the aim to show the large complex of work carried out in a purely medical aspect of radiation protection. It is an independent part of work though almost the leading one in the problem of protecting people exposed to radiation. We only want to note that various types of medical examinations were carried out on a mass scale (about one million people and 700 000 of them including 216 000 children were examined carefully using dosimetric and laboratory measurements and analysis). Children in whom a radiation dose from iodine radionuclides to the thyroid could exceed 0.3 Sv were subjected to constant medical survey.

Efficiency evaulation of the whole complex of prophylactic and protective measures carried out for the first two years after the accident makes it possible to believe that they resulted in a decrease of radiation doses to the thyroid averagely by 5-20 times, external irradiation doses by 1.3-2.5 times depending on occupation and age and internal irradiation doses from radiocesium by 10 and more times.

Analysis of the radiation situation performed with an account of the protective measures allows us to state with confidence the following:

- not a single case of radiation injury has been found in the population exposed to irradiation;

- average radiation doses to the critical population groups did not exceed the main temporary dose limits for the first and the second year after the accident established by the Ministry of Health (0.1 and 0.03 Gy, respectively);

- doses of external irradiation to the population permanently living at the contaminated territories did not exceed 0.05 Gy and 0.02 Gy for the first and the second year, respectively;

- doses of internal irradiation from incorporated radionuclides of cesium did not exceed 0.05 Gy for 99 per cent of the population in the regions under control in the first year and Gy for 92 per cent in the second year. Comparing to the summer of 1986 the content of cesium radionuclides in the body of residents of the controlled regions decreased in summer of 1987 averagely by 2-5 times and in some persons by 7-10 times;

- in 1987 due to effective measures the contribution to the dose from internal irradiation was averagely 10-30%.

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DISCUSSION

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In accident impact mitigation radionuclide diagnostic specialists may be of great help. This service involves highly qualified staff as well as contemporary equipment,and is available in every town. It has to be the centre of gamma-spectrometry for evacuated and migrating population. That may help to increase the quality of public health service and decrease the level of radiophobia.

J. WADDINGTON (WHO)

BRIEF SUMMARY OF THE ONGOING PROGRAMME OF WHO IN RELATION TO THE PUBLIC HEALTH ASPECTS OF NUCLEAR ACCIDENTS AND THE CHERNOBYL FOLLOW-UP

First of all, priority is being given to the effectiveness of the service which WHO can offer to member states following any future accident, based on experience gained after Chernobyl, when although the organization had an emergency room in operation work quickly. After first indications of enhanced radioactivity levels on 26 April 1986, the system was essentially of an ad hoc character.

The continuency planning now in progress is being carried out in close cooperation with IAEA and WHO and in a fact inter-secriat meeting is being held next week.

Following the interim report on dose commitment published by WHO last year, WHO has assisted UNSCEAR in gaining data for their own reports to be published later this year. A detailed report gas also been issued by WHO on the position throughout Europe in relation to cesium deposition and its public health consequences.

After Chernobyl, there was widespred confusion among member states on measures imposed to control foodstuffs and this contributed to public scepticism and disbelief. The systematic derivation of recommended derived intervention levels had now been completed and has been approved by WHO's Executive Board. FAO have concentrated on the development of an essentially simple system suitable for international trade whilst WHO has, clearly, a duty to safeguard public health.

These FAO and WHO approaches are now being looked at through and the two organizations will be putting forward proposals on derived intervention levels for foodstuffs to Codex Alimentarius in 1989, based on a figure of 5 mSv in the first year.

A "milestone" working group was held in Geneva in November 1987 to harmonise public health measures in relation to nuclear accidents. As a direct folling-up, an important meeting will take place in Netherlands in October. To look in detail, at the situation in the near field (close to a nuclear accident), covering medical care, sheltering and evacuation.

In relation to sheltering and evacuation, in particular, there are important psychological dimensions and this will be a major centre of focus. Indeed the psychological aspects involved in nuclear accidents and the public perception of relative risk from different energy options are becoming major elements of the WHO programme.

WHO is, in the light of Chernobyl experience, looking at iodine prophylaxis with a view to issuing detailled guidelines by the end of 1988. The second workshop to develop these will be held in Brussels in two months' time. Scientific and medical aspects will be coverd, the application to specific population groups, possible adverse side-effects and practical aspects of storage and distribution.

Detailed public health guidence related to the far-field including transfrontier consequences will be developed at a meeting in Switzerland in January 1989.

Finally, Mr.Chairman, I would like to refer the question of epidemiological follow-up. This was examined at two successive meetings held in May 1987 and a detailed report issued. Outside the Soviet Union, a number of important studies are in progress, including a Polish programme into the effects of iodine prophylaxis and European Community (Eurocat) study of congenital malformations.

The International Agency for Research into Cancer (IARC) is collaborating with the European office of WHO in a study of childhood leukaemia incidence using cancer registries in 15 European countries. Leukaemia has been selected as it appears relatively soon after exposure and it ia a particularly sensitive of radiation exposure. The background level is low, and varies rather little in comparison with other cancers, and there are known variables which strongly influence risk. It allows the possibility of including several countries which do not register all cancers but which do register childhood cancers.

Data will be centrally analysed by IARC with particular reference to spatial and temporal variation and estimated levels of exposure from Chernobyl, by region, in collaboration with UNSCEAR.

Although, outside the near field area, it will be very difficult to detect any effects, the study can be justified as:

1) it can help to determine an upper growth on the level of risk;

2) knowledge of the variation in childhood leukaemias will be useful in future evaluation of clusters;

3) exposure, following the accident, while low in absolute terms, represents a step increase, of a multitude comparable to background in several countries.

Of course, the greatest interest is in the area close to the accident in both this and other epidemiological studies and we have heard a lot about this today.

At policy level, the World Health Organization in Europe has given high priority to epidemiological studies. The first consultation on epidemiology following Chernobyl asked WHO to examine the flasibility and practical usefulness of establishing a steering group and clearing-house.

It has been emphasized that such a body should not seek to put undue pressure on any country either to carry out particular studies or in their detailed design. It would be a sound box for new ideas and a register of what was going on and the results. Above all, it must represent a meeting of scientific minds and not develop an unnecessary complicated burocratic structure. Its meeting must be set up progmatically, depending on optimal needs and timing.

A second international consultation on epidemiology following Chernobyl is accordingly being organized by WHO and IARC, to take place in the Autumn of 1988.

G.W. ANDERSON (Canada), **E.D. RUBERY** (United Kingdom)

Epidemiological follow-up of the most exposed individuals (100,000 Plus) will be of great value as a source of reassurance to the general population.

It is probable that there will never be a detactable increase in cancer or other diseases in these most exposed individuals. Reports should therefore be regular and frequent ($\approx$ 1/ year) in order to reduce anxiety in all concerned people.

Collaboration with the proposed expert group of the World Health Organization will provide valuable assistance, and will increase the general credibility and acceptance of the results.

DOSES OF EXTERNAL AND INTERNAL RADIATION EXPOSURE

METHODOLOGICAL PRINCIPLES FOR CALCULATING LEVELS OF EXTERNAL AND INTERNAL EXPOSURE OF THE POPULATION USED IN TAKING STRATEGIC DECISIONS

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Abstract

The significance of each of the factors involved in internal and external exposure of the population can vary considerably as a function of the specific exposure conditions or the time which has elapsed since the accident. If data on the radionuclide composition of the fallout are available, dose rate dynamics can be calculated in accordance with the law of radioactive decay for the mixture of interest. After four years the reduction in the dose rate follows the law of caesium-137 decay in soil, and the effective period of removal of half the radioactivity from the body is $T^{eff}_{1/2}$ = 14 years (Biophysics Institute of the USSR Ministry of Health) (according to other data 7 or 5 years).

In the first year after the accident, the effective dose equivalent to the human body was determined by strontium-90 and strontium-89. The EDE for subsequent years and the integrated 50-year EDE will be governed almost completely by strontium-90.

1. The present "Methods of Calculating" were used for calculating the radiation levels to which the population living near Chernobyl was exposed and which were required for substantiated development and realization of various measures directed at a maximum decrease of human irradiation.

In this connection we used approaches based on theoretical considerations, accumulated experience and direct experimental data obtained by the examination of the radiation situation under consideration and supposed to take into account the local specification of human irradiation and to proceed from the critical (by their radiation sensitivity) population groups.

It should be noted that the dose assessments obtained are of conservative nature and essentially represent an upper estimation of the dose commitments.

2. To provide a strict consideration of the conditions and the character of radiation exposure the doses of external, contact and internal irradiation have been calculated.

External irradiation includes:

- gamma radiation dose from the radioactive cloud (D_{cl}) formed during the period of its passage and track formation and as a result of an effect of a flow of flying radioactive fallouts and gases;

- gamma radiation dose from the deposited radioactive fallouts (a track of the radioactive cloud) (D_{tr});

- beta-ray dose to the human skin from the environmental radioactive contamination (D_{sk}).

Of the local population was evacuated but is supposed to return back (reevacuation) the dose of external irradiation from the radioacitve fallouts will be formed by the corresponding doses received before the time of leaving (t_1) and the doses received after coming back (t_2). In this case the time internal (t_1-t_2) will be a duration of the evacuation.

Internal human irradiation is essentially determined by

- the dose to thyroid (Th) formed by the radionuclides of radioactive iodine concentrated in the thyroid;

- the dose of lung irradiation due to inhalation of radioactive products;

- the dose of gastrointestinal irradiation due to exposure to radioactive products penetrating the body by the inhalation or oral routes of intake and eliminated through the gastrointestinal tract;

- the dose of soft tissue irradiation due to accumulation of the radioactive cesium getting into the body mainly with food;

- the dose of bone tissue irradiation due to strontium-90 being accumulated in them.

3. Depending on the real radiation conditions and (or) on the time elapsed after the accident the significance of each of the above given factors of external and internal human irradiation can be different. This fact should be taken into account and provide priorities in the dose calculations.

4. The doses of external irradiation were calculated with the use of connections and coefficients presented below.

4.1. The radiation dose from the cloud (D_{cl}) is estimated by three independent methods.

The first one uses data of the direct measurements of summary gamma doses by the dosimeters UKC located beforehand (before the accident) around the Chernobyl plant at the distance of 1.5-50km as a measure of the constant control.

If the time of taking off readings from the dosimeters counted from the moment of the accident is ($t_{read.}$) and D_d^{Σ} is a dose registered by the dosimeter then the dose from the cloud ($D_{cl.}$) will be

$$D_{cl} = D_d^{\Sigma} - D_{tr}\left(t_{read}\right) \quad , \quad \text{where}$$

$D_{tr}\left(t_{read}\right)$ - gamma radiation dose from the radioactive fallouts for the period beginning from the moment of accidental release and up to t_{read}. Actually $t_{read.}$ was 7...10 days (determined after the passage of the cloud).

The second method is based on the doses to the thyroid determined by direct measurements of its radioiodine content in adults who neither consumpted milk nor used iodine as prophylaxis. According to the data obtained by generalizations the dose from the cloud in this case can be estimated by the equation:

$$D_{cl} = 0.01 D_{th} \, , \quad \text{where}$$

D_{th} - dose to the thyroid measured within 5-10 days after the accident (inhalation component).

The third method is based on calculations of predictional estimates of the radiation parameters around plant for various types of accidents:

$$D_{cl} = 0.1P_\gamma \quad (t=15) \quad \text{where}$$

D_{cl} in rads, P_γ in mR/h on the 15th day after the accident.

The estimations made by these methods show that the dose from the cloud will be not more than 20 per cent of the fallout dose formed on the 15th day after the accident. It is assumed that the dose from the cloud will be 10 per cent of the annual dose from the fallouts as a maximum estimate of its value.

4.2. Irradiation from the track. The data of actual observations over the variations of the dose rate at the height of 1 m from the ground surface and predicted dose values for the next years are given in Table 1.

Table 1.

time after the accident	dose rate mR/h	dose absorbed in the air up to the given moment, P
1 day	3	0.43
4 "	2,5	0.57
7 "	1.7	0.72
15 "	1.0	0.9
1 month	0.55	1.2
3 "	0.22	1.7
1 year	0.074	2.5
3 "	0.039	3.4

For practical purposes an analitical expression describing the variations of the dose rate in Table 1 at the time $t > 15$ days has been assumed:

$$P_\gamma(t) = 7.5 \cdot P_\gamma \; (D+15) \cdot t^{-n}$$

7.5 - P value extrapolated to 1 day for the isoline

$P_\gamma(D+15) = 1$ mR/h where

$P_\gamma(D+15)$ - dose rate on the 15th day;

t - time moment, day.

For the actual mixture the value of $n = 0.6 \div 1.3$ with D+15 (on the $10^{\underline{th}}$ of May).

If the data on radionuclide composition in the fallouts are available the variations of the dose rate are calculated by the law of radioactive decay in the given mixture.

Beginning from the $4^{\underline{th}}$ year a decrease of the dose rate follows the law of diminishing cesium-137 in the soil with $T_{1/2}^{eff}$ = 16 years (by the data of the Institute of Biophysics) or 7.5 years (by other literary data).

To provide an assessment of the annual radiation dose equivalent to the whole body the following attenuation coefficients have been assumed:

- transfer from the expositional dose to the dose absorbed in the air - 0.87;
- deep penetration of cesium-137 into the ground (begins from the second year) - 0.6;
- screening by the snow - 0.7;
- behavioural conditions with the account of screening by buildings and the time spent indoors and outside: for those living in the town: 0.4; for those living in the country: 0.75. The summary coefficients for the first year are 0.24 and 0.46 for those living in the town and in the country, respectively. For the second year: 0.15 and 0.27 for the town and the countryside, respectively.

4.3. Skin irradiation by beta-rays. The radiation dose to the skin due to soil and plant contamination is estimated by the contamination density of the surface σ, Ci/km^2:

$$R_{\beta}\,(\text{skin})(\text{rem/d}) = 1.5 \cdot 10^{-3} \sigma$$

It is supposed that $E_{\beta max}$ of the radionuclide mixture will by about 1 MeV.

5. The doses of internal irradiation were calculated with the use of connections (links) and coefficients presented below.

5.1. Irradiation of the thyroid.

If direct measurements are not available irradiation of the thyroid is estimated by the data of radioactive content in milk It is assumed that up to June 1 90 per cent of gamma-radioactivity in milk was due to iodine-131. If neither direct measurements nor data on iodine-131 content in milk is available an approximate upper estimation of the radiation dose to the thyroid in the critical population group (children) can be obtained by the ratio:

$$D_{th}(\text{rem}) = 100\ P_{\gamma} \qquad (\text{mR/h}).$$

This method of the dose estimation is very approximate and cannot be used for clinical purposes.

5.2. Irradiation of the lungs. The dose of lung irradiation by inhaled radionuclides can be obtained by the following ratio:

$$D_{\beta}\ (\text{lungs}) = 0.7\ D_{inh}(\text{Th})$$

5.3. Irradiation of the gastrointestinal tract. In estimating irradiation of the gastrointestinal tract we considered only the lower small intestine (ISI) as a part mostly subjected to irradiation. An approximate estimation can be obtained by the equation:

$$D_{\beta}\ (\text{LSI}) = 10{,}4\ D_{\beta}\ (\text{lungs})$$

5.4. Irradiation of the whole body due to cesium intake with food .

5.4.1. The first year after the accident. During the first year cesium intake with food is determined by the contamination penetrating by routes other than plant roots. The calculations assume: the retention coefficient on the pasture plants with the biomass of 1 kg/m^2 is 0.4-0.2; cesium content in grass is described by a two-component exponential model with half-lives of 3 days (70%) and 50 days (30%):

$$q_g(t)=0.2[0.7\exp(-0.231t)+0.3\exp(-0.014t)]\cdot\sigma \qquad (1)$$

σ - fallout density, 10^{-6} Ci/m^2

Duration of the pasture period is six months, hay is laid in during the last three months of the pasture period. Grass consumption by a cow is 50 kg/day, the half-life of cesium-137 in the body of a cow - 30 days the fraction eliminated daily with milk - 0.13 or 0.013 per litre of milk (average daily milkyield - 10 l). The calculation of cesium content in milk before the cattle is transferred to the stall feeding is performed by the equation:

$$q_M(t)=0.013q_d\cdot\lambda_c\left[\frac{0.7}{\lambda_1-\lambda_c}(e^{-\lambda_c t}-e^{-\lambda_1 t})+\frac{0.3}{\lambda_2-\lambda_c}(e^{-\lambda_c t}-e^{-\lambda_2 t})\right] \qquad (2)$$

where q_d - daily intake of cesium-137 into the body of a cow equal to $q_g^o\cdot 50$ (q_g^o- initial contamination of the grass); λ_c - constant of the biological half-life of the radionuclide in the body of a cow - 0.023 days^{-1}, λ_2=0.014, λ_1=0.231.

During the stall feeding cesium concentration in hay is assumed as a constant, equal to the mean grass concentration during haymaking and is determined by the equation:

$$\bar{q}_g=\frac{0.2}{t_h}\left[\frac{0.7}{\lambda_1}(1-e^{-\lambda_1 t_h})+\frac{0.3}{\lambda_2}(1-e^{-\lambda_2 t_h})\right]\sigma. \qquad (3)$$

where t_h - average period of haymaking. For the first year cesium-I34 content in gross and milk is calculated with an assumption of the ratio of its concentration in the fallouts to the concentration of cesium-137 remaining 1:2 - 1:1.5.

5.4.2. The second year after the accident. During the second year the factor which determines food contamination will be radionuclide intake through the soil. The radioecological characteristics of the Ukrainian-Byelorussian Polesye, the region which was mostly contaminated by the accident, determine a high degree of cesium mobility and as a result of that the coefficients of its transfer from the soil to the plants exceed by tenfolds the similar values in other regions of the country (for example, by 1.5-15 times for milk). Therefore in estimating the doses in this or that region one should use transfer coefficients which correspond to the soil characteristics and were obtained for the conditions of the cesium-137 world fallouts assuming that availability of the local cesium is similar to that of the world cesium (at least before the new data are obtained). In this case an average annual content of cesium in milk is sufficient for the practical purposes and can be obtained by the equation:

$$q_m(Ci/l) = K_m \cdot \sigma_{soil} \qquad (4)$$

where K_m - cesium transfer coefficient in milk, $Ci/l/Ci/km^2$; $(3.5 \cdot 10^{-9})$

σ_{soil} - cesium content in soil, Ci/km^2.

Cesium content in the daily diet of man is determined by the similar method using the link coefficients for the diet as a whole or by recalculating from cesium content in milk assuming that milk determines up to 70 per cent of the daily intake of cesium into the human body in the BSSR and up to 30 per cent in the UK SSR. During the second and subsequent years the ratio of cesium-134 to cesium-137 varies according to the differences in their half-lives. In future the elimination process from the soil (due to many factors: radioactive decay, washing out by the surface water, etc.) should be also taken into account the half-lives being 14 (or 7.5) and 1.75 years for cesium-137 and cesium-134, respectively.

5.4.3. Determination of cesium content in the human body.

Cesium content in the human body towards the end of the year when contaminated food has been consumpted is mainly determined by the intake in that particular year. If cesium content in the daily diet is constant (it can be assumed with sufficient accuracy beginning from the second year) then cesium accumulation in the body can be described by the following dependence:

$$Q(t) = \frac{q_r f}{\lambda_e} (1 - e^{-\lambda_e t}) \qquad (5)$$

where q_r - daily intake with the diet, Ci/day;

f - coefficient of absorbtion from the gastrointestinal tract equal to 1;

λ_e - constant of the effective half-life of cesium in the human body, equal to $6.3 \cdot 10^{-3}$ days^{-1} and $7.16 \cdot 10^{-3}$ days^{-1} for cesium-137 and cesium-134, respectively (adults). For children the biological half-life is determined by the equation:

$$T^{\delta}_{1/2} = 12.8(t^{1/2} - e^{-t}) \text{ days} \qquad (6)$$

where t - age of achild, years.

The empirical ratio for an adult giving average annual cesium content in the body in the conditions of a chronical constant intake can be also used:

$$Q(t) = 120 q_r \text{ Ci/body} \qquad (7)$$

where q_r - daily intake of the radionuclide with food, Ci/days.

If radionuclide content in the diet varies its content in the body is described by the following equation:

$$Q(t) = e^{-\lambda_e t} \int_0^t q_r(\tau) e^{\lambda_e \tau} d\tau \qquad (8)$$

The final form of the equation depends on the specific form of the variation function of cesium content in diet or in milk as a main component of the diet. In particular, during the first year when the cattle is feeding at pastures and when cesium content in milk varies cesium intake into the human body may be described by the equation (2) adjusted to the diet as a whole.

5.4.4. Assessment of the dose equivalent due to cesium radionuclides.

The dose equivalent to the soft tissues for a certain time internal, T, is a product of the integral of body content for that period by the dose rate coefficient:

$$D(T) = d_o \int_0^T Q(t)dt \text{ , rad} \qquad (9)$$

where

d_o - dose rate coefficient, rad/day/Ci/body;
T - duration of the time period considered, days;
Q(t)- body content, Ci/body.

The dose rate coefficients used with calculations are:
d_o(for cesium-137) = 3.6 10^2rad/day/Ci/body
d_o(for cesium-134) = 6.1 10^2rad/day/Ci/body.

Table 2 gives an example of internal irradiation calculated for the first year on the condition cesium-137 fallouts were 1 Ci/km^2 with the contribution from cesium-134.

During the second year irradiation of the body is determined by cesium intake with food consumpted in that year and partially in the first year. Contamination of the diet during the second year is due to the intake of radionuclides into agricultural products trough the roots and therefore contrary to the first year contamination levels of the diet will be essentially different depending on the local soil characteristics which influence cesium transfer into the plants and food of the local origin. The difference of coefficients linking cesium-137 content in the diet as a whole and in the soil will be (2-20)$\cdot 10^{-9}$ Ci/diet per 1 Ci/km^2 and 0.2$\cdot 10^{-9}$ Ci/diet per 1 Ci/km^2, a value for the

Table 2.

time before removal to other regions	Doses, mrem (up to May 1, 1987)				
	1	2	3	4	5
10 days	9.0	240	249	560	310
20 days	18.3	240	258	560	302

Note: 1 - dose for a year from intake to removal to other regions;

2 - dose formed before May 1, 1987 from the intake after coming back;

3 - summary dose due to the factors 1 and 2;

4 - dose received in the absence of removal to other places;

5 - dose excluded by the removal to other places. The contribution of milk to the summary intake is 30-70 per cent for different regions (it is important and should be taken into account in the recommendations).

Ukrainian-Byelorussian Polesye and a mean value for the whole country, respectively.

If to accept a sufficiently moderate value of the link coefficient ($5 \cdot 10^{-9}$), the dose for the second year after the accident due to intake of that year will be 0,19 rem/year and the summary dose - 0,29 rem/year.

It should be noted that all these calculations were made for the adult population, a critical group for cesium. The levels of radiation doses to children are somewhat lower but for older ages they can achieve the given values.

5.5. Irradiation of the human body due to strontium intake.

During the first year after the accident the effective dose equivalent (EDE) is determined by strontium-90 and strontium-89. In subsequent years the integral committed EDE is also practically completely determined by strontium-90.

6. The next stage of dose calculations was based on the data of direct measurements of iodine and cesium content in the human body, on selected individual dosimetric control and on the real decrease dynamics of the dose rate in every populated location in the controlled zone. The detailed recommendations to the calculational methods were considered and approved by NCRP of the Ministry of Public Health, USSR. Improvement of the absorbed dose calculation methods is directed now towards the maximum individualization of the dose burdens. For the radiation doses from iodine-131 this paper includes a credibility analysis of the original information and specification of the conditions for radionuclide intake into the body. For the doses of external irradiation the data presented here include detailed distribution of individual radiation doses according to the occupational-age groups on the base of data of individual dosimetric control being accumulated and results of the profound examination of the dose field within the controlled area. For the doses of internal irradiation from absorbed cesium radionuclides we present a scientific analysis of the efficiency of some radiation-hygienic measures.

DYNAMICS OF GAMMA RADIATION LEVELS AND FORMATION OF EXTERNAL EXPOSURE DOSE

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Abstract

From the first day after the accident, gamma radiation fields throughout the country were systematically observed and data collected and analysed. In the first stage, the availability of such dynamic data for each population centre made it possible to obtain reliable estimates of external exposure doses to the population up to the time of evacuation, which, in the majority of centres evacuated, did not exceed 0.1 Gy and in the others did not exceed level B (0.75 Gy) taken as the upper level.

The decontamination measures carried out made it possible to reduce the exposure dose by a factor of 1.3-2.5 in comparison with the anticipated doses for different occupational and age groups. The maximum reduction was noted in children.

The external gamma-irradiation from the fallout is one of the main radiological factors of the accidental releases from IV power unit of the Chernobyl NPP affecting the population. According to assessment conducted by the Soviet specialists, the external irradiation contribution into the total dose did not exceed 50% during the first post-accident year, and about 60% for the whole life period.

Determination of dose loads was based on the data about the gamma dose rate dynamics in towns and their economical areas, considering the behavior regime of the population. Systematic observation over the gamma-radiation field in the whole country, regular collection and analysis of the information were launched on the second day after the accident. Data about gamma dose rate and it's dynamics, obtained by aviation and terrestrial survey, were the most important factors, which were taken into consideration while decision making about evacuation of the population and taking measures concerning liquidation of the accident consequences and population dose reduction.

According to this factor, the radiological situation in it's progress may be divided into two stages:

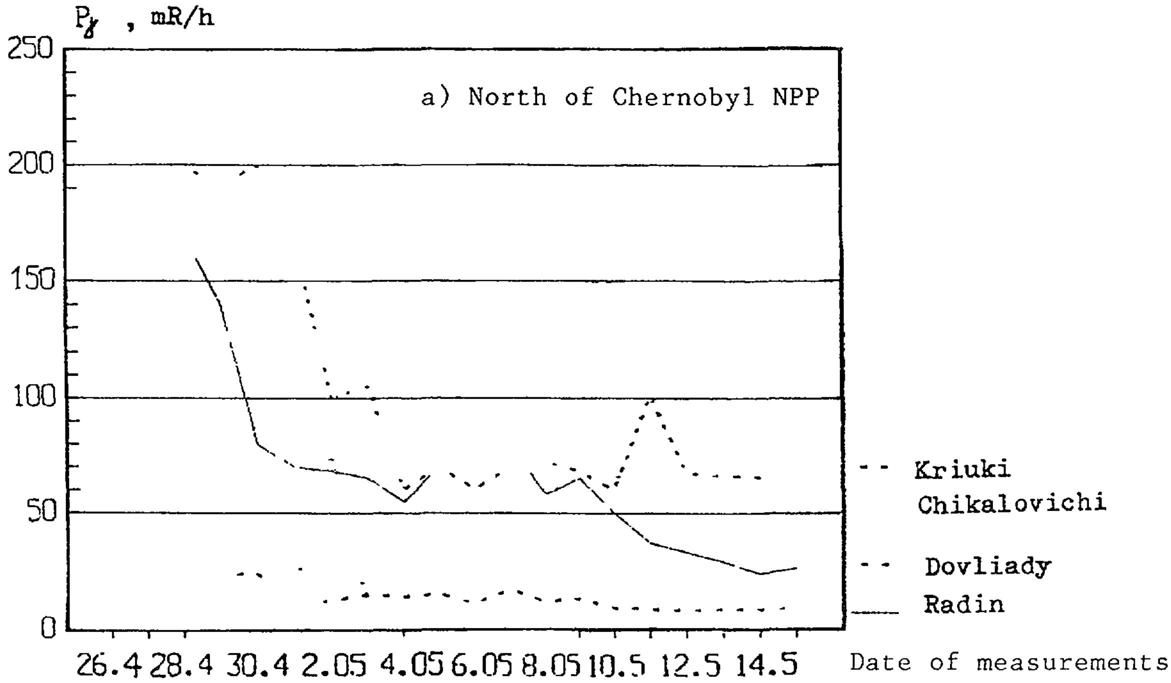
- (I) since the moment of the accident till IO May I986;
- (2) since IO May I986 till today.

First stage. Dose field formation was determined by dynamics of releases from the accidental power unit, as well as by the meteorological conditions in the Chernobyl NPP zone and the direction of the air mass movement, transporting the radioactive products. In the nearest zone three radioactive traces were being formed: western southern and northern. Inside each trace the nuclide composition of the radioactive fallouts was heterogenic and density of surface contamination was spot-like. That, as a rule, led to stepped increase of gamma dose rate.

On Fig. I the dose-rate dynamics in several settlements, situated in the range I7-22 kilometers around the Chernobyl NPP site in different azimuthal directions is shown. Influence of radioactive cloud and streams on the dose-rate dynamics may be clearly seen on this figure.

Doses, formed by the irradiation from the cloud were assessed using data about the total gamma doses obtained with dosimeters of IKS type (placed around the NPP site before the accident at the distance I.5-50 kilometers), and the fallout gamma dose, formed during I5 days after the accident. Assessment showed that the cloud dose did not exceed 20% of the fallout dose during the mentioned period. This assessment is in satisfactory agreement with the results of theoretical estimations and the value obtained from the correlation between the inhalation uptake of radio-iodine by thyroid gland and the radioactive cloud dose.

Dynamic data for every evacuated settlement made possible the reliable population dose assessments. These doses for the majority of evacuated settlements did not exceed o.I Gy, and for the rest were less than level B (0.75 Gy), adopted as the upper limit in



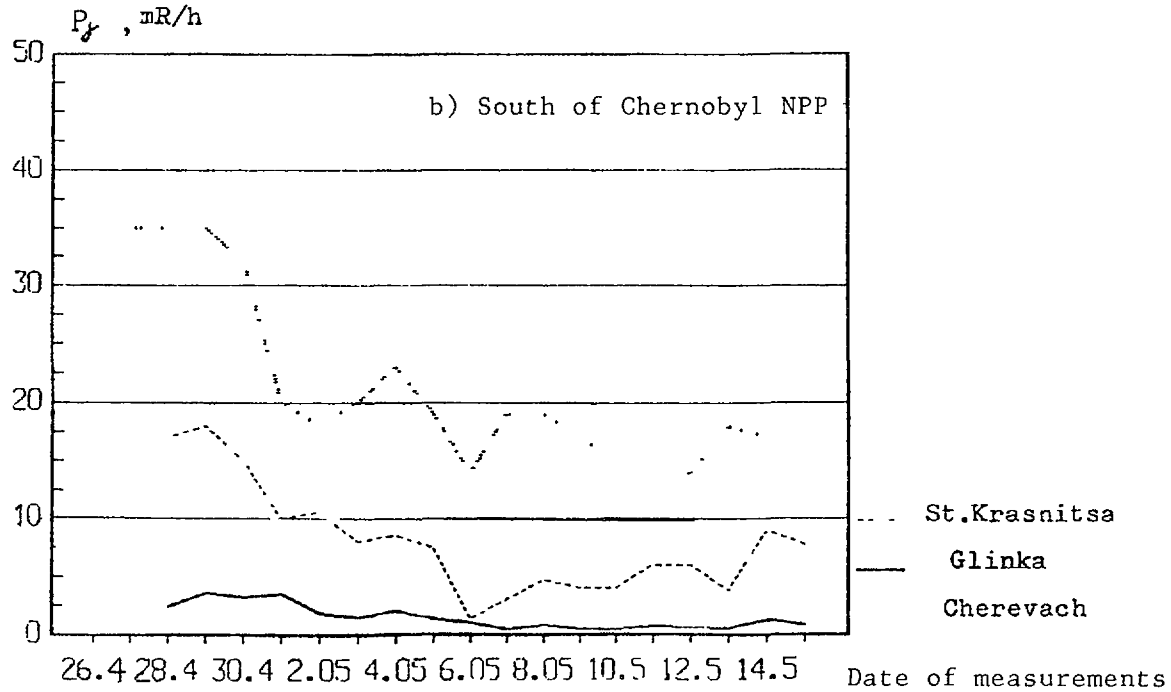


Fig.I. Dynamics of gamma-dose rate in the settlements where the evacuation was carried out.

the "Criteria for decision making for population protection in case of reactor accident".

Second stage. Dose rate during this period mainly depends on radionuclide composition of the fallout. Certain influence on the gamma dose rate dynamics has the sublimation of the volatile radionuclides while soil hearting, secondary wind transport, precipitation, snow shielding of gamma-irradiation, vertical migration of radionuclides in soil, etc.

On Figs. 2-8 dose field dynamics during the first year after the accident in the regions, situated to the north from the Chernobyl NPP site is shown. Dose-rate is related to I Ci/km 2 density of the surface contamination of soil with Cs-I37. Figures show that dose rate decrease since IO May I986 in the absence of snow layer may be good approximated with Vey-Vigner degree law with degree indices of 0.6-I.3.

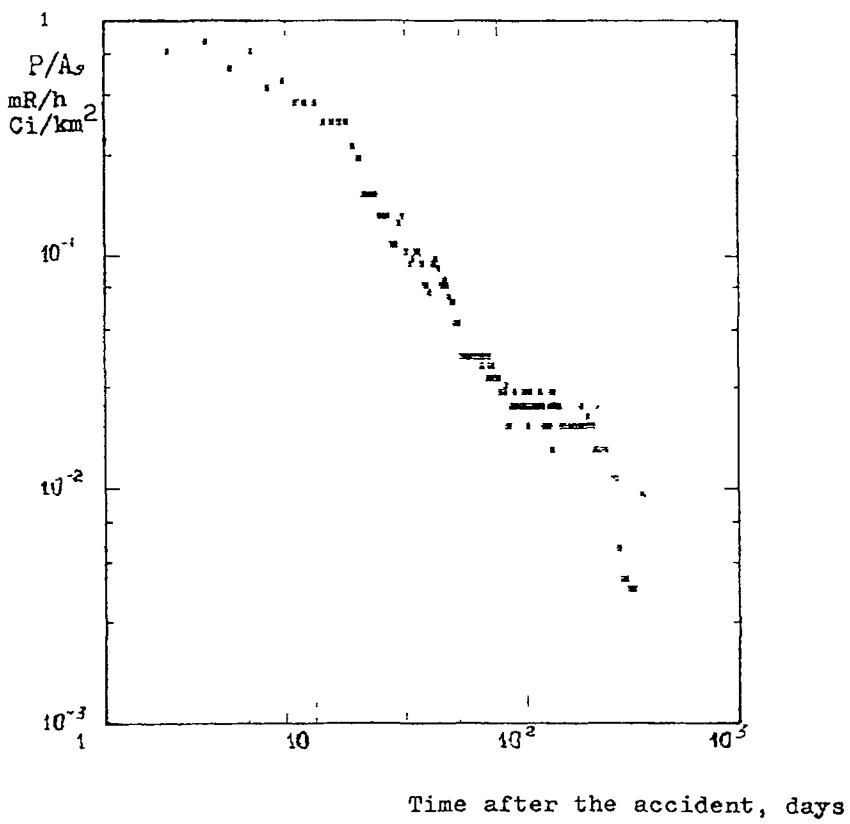


Fig.2. Dynamics of gamma-dose rate in the open area (Braginsky district).

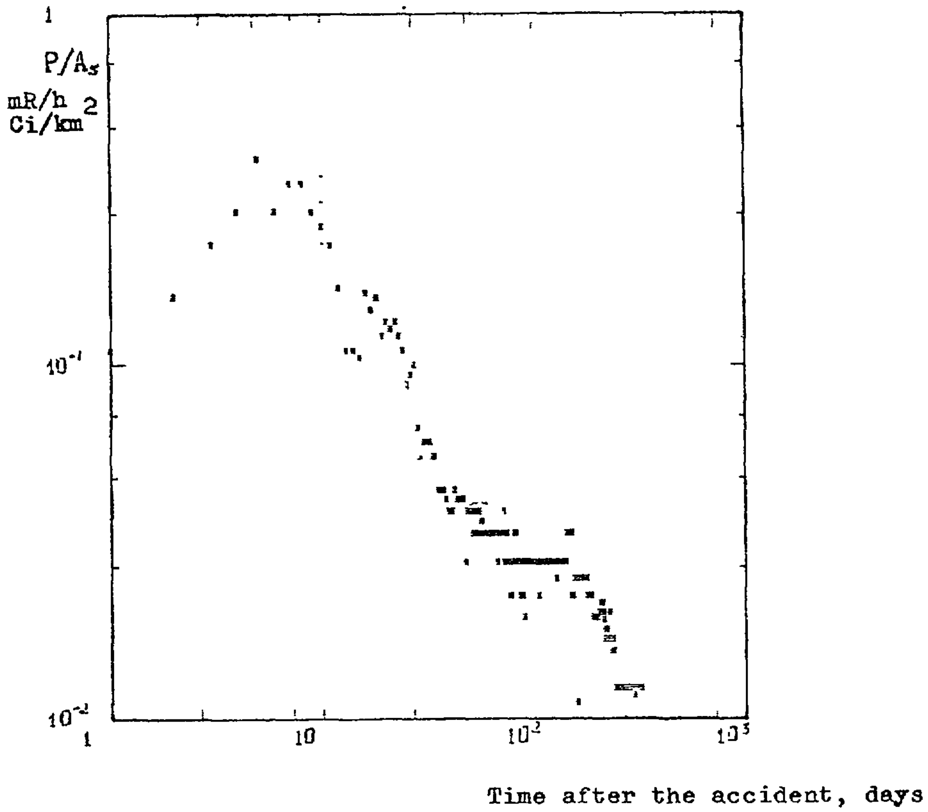


Fig.3. Dynamics of gamma-dose rate in the open area (Khoiniksky district).

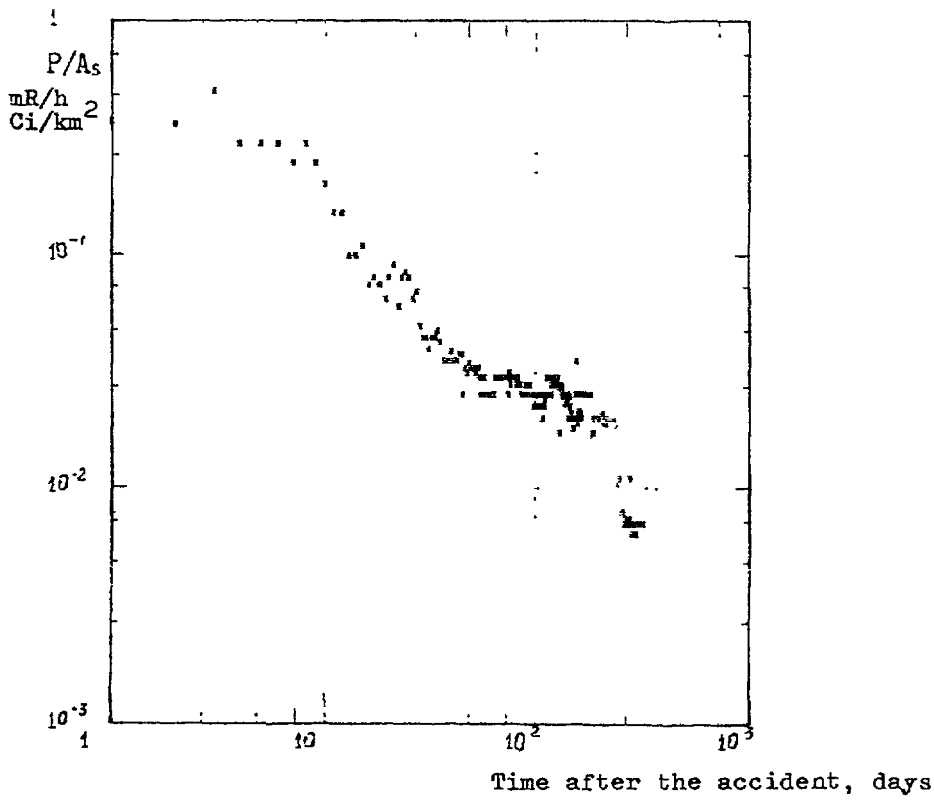


Fig.4. Dynamics of gamma-dose rate in the open area (Narovlyansky district).

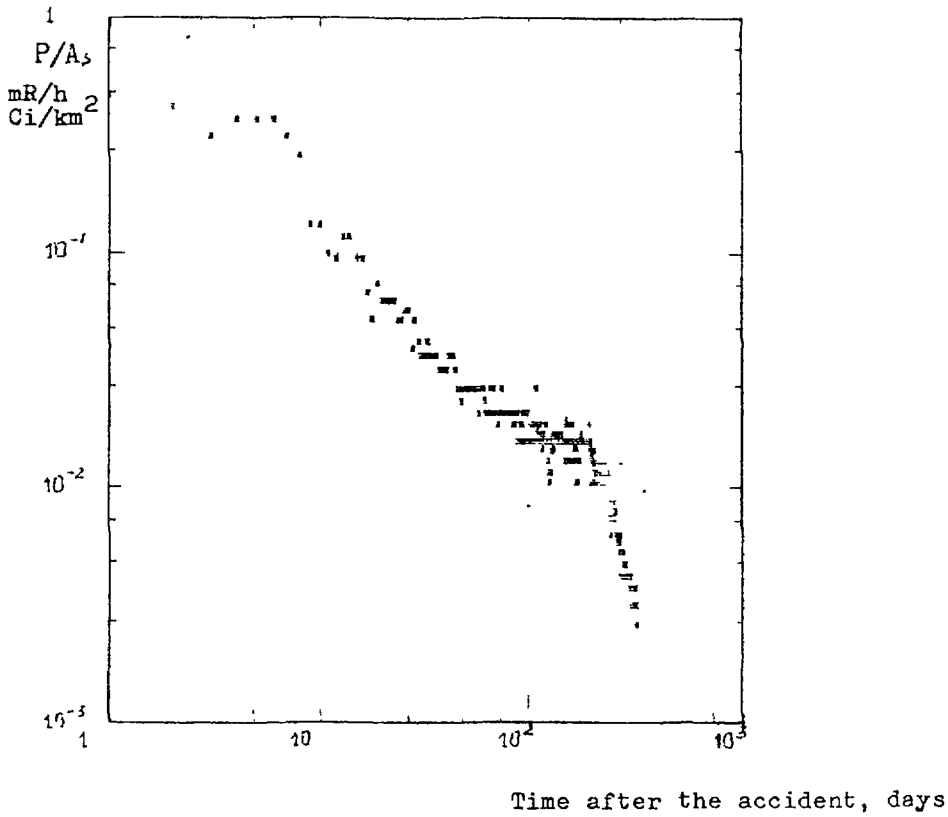


Fig.5. Dynamics of gamma-dose rate in the open area (Vetkovsky district).

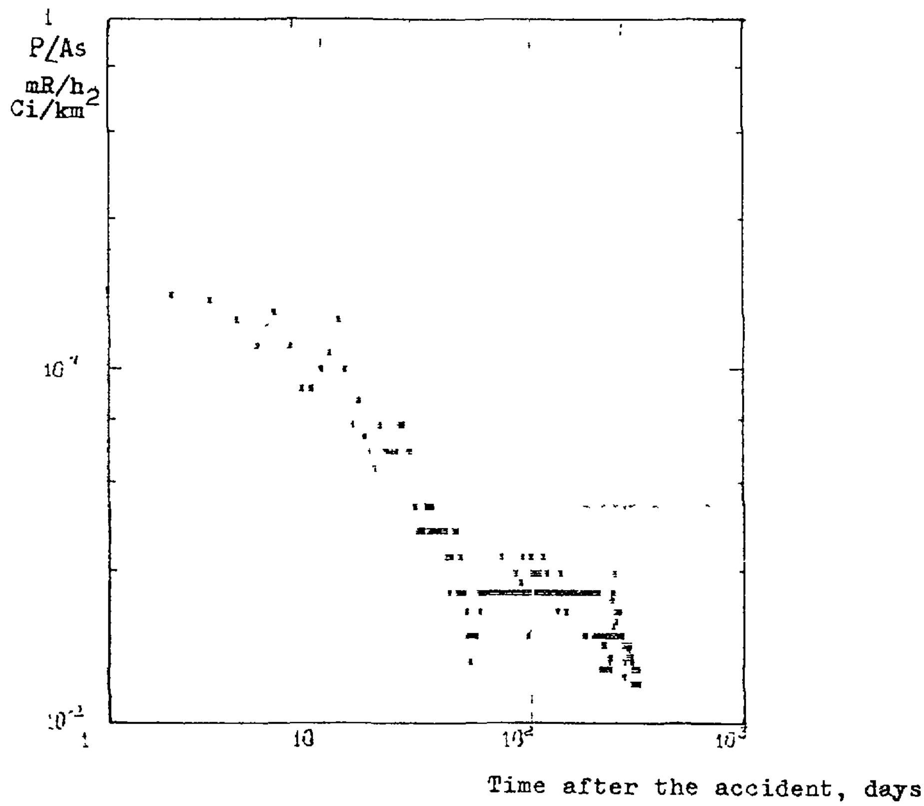


Fig.6. Dynamics of gamma-dose rate in the open area (Chechersky district).

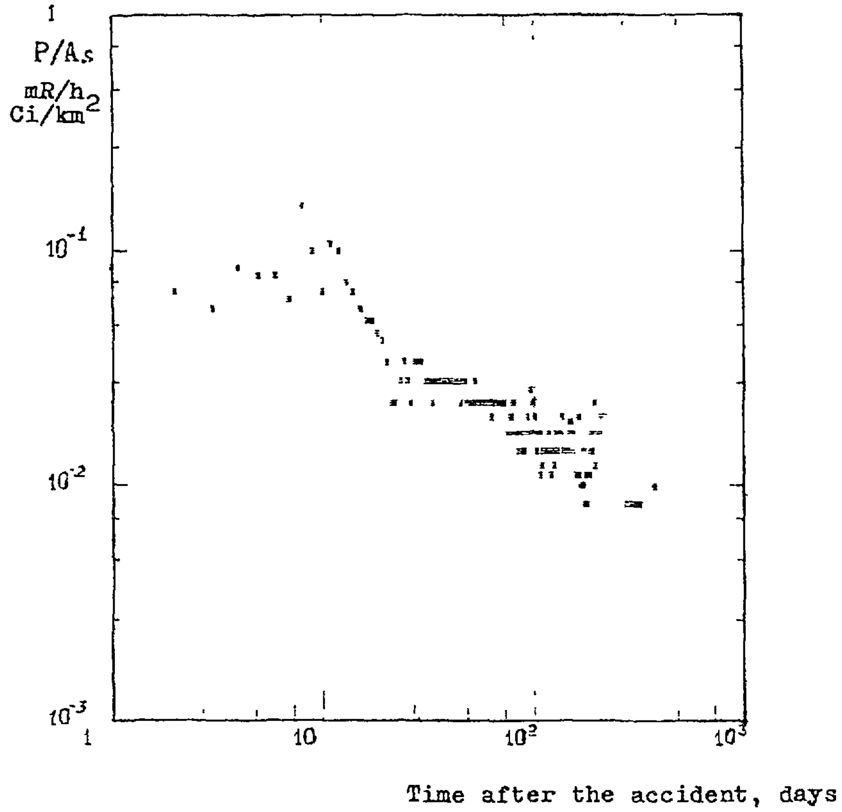


Fig.7. Dynamics of gamma-dose rate in the open area (Kormyansky district).

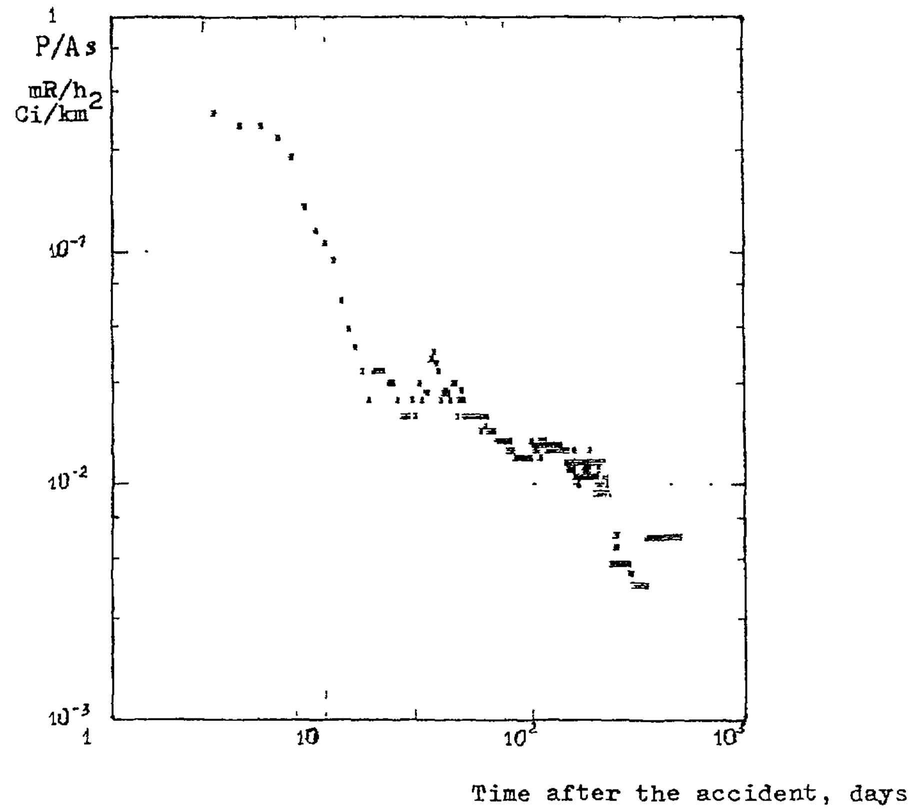


Fig.8. Dynamics of gamma-dose rate in the open area (Novozubovsky district).

Influence of the heterogeneity of the gamma-emitting radionuclide composition inside the northern trace is illustrated by fig.9, where the outdoor dose accumulation dynamics during the year is presented. As is shown on the figure, for Bragin region the first half of annual dose was accumulated during the first 0,5 month, for Khojniky region - I.6 month, Narovlja region - 2.5 month, Novozybkovo region -3.I month.

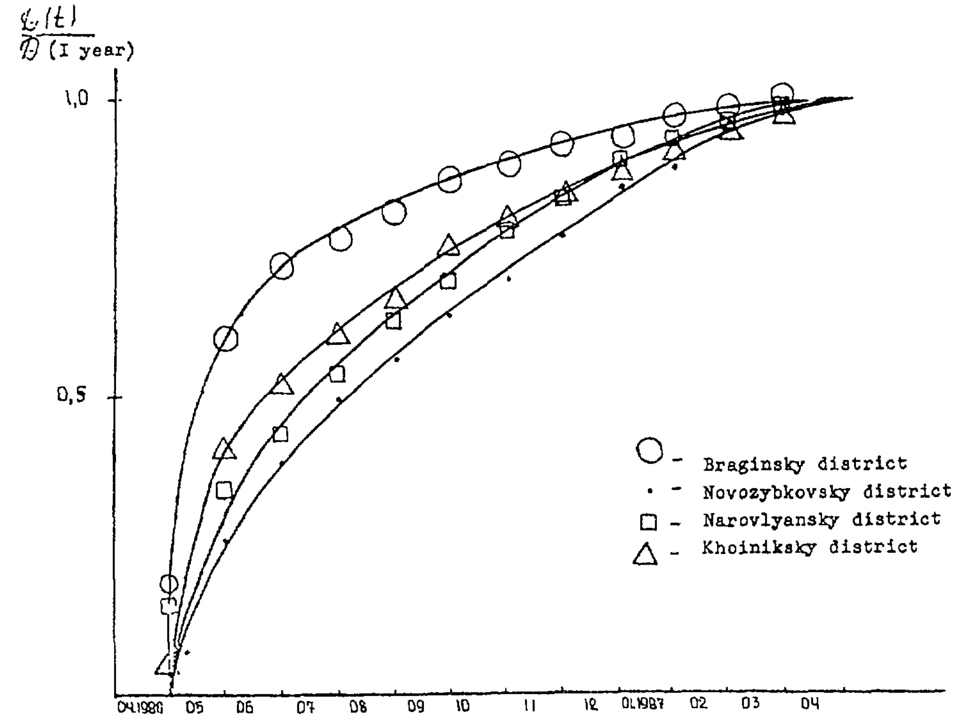


Fig.9. Dynamics of dose accumulation in the open area during one year.

Deviation of the experimental curve from the Vey-Vigner law during the winter period I986-I987, was connected with the gamma-shielding effect of the snow layer. In February I987 the shielding ratio reached the value of 3-4. After the snow melting in the April, dose rate increased rapidly and experimental points approached the theoretical curve again.

Certain decrease of dose rate was caused by effect of the vertical migration of radionuclides in the soil. According to data of Institute of Biophysics (USSR Ministry of Health) the vertical migration may be satisfactorily described with the following equation:

$$q(h)=\begin{cases} 0.3\ A_s/h_o + \frac{0.7\ As}{\lambda}\ e^{-h/\lambda} & 0 < h < 0.0I\ m \\ \frac{0.7\ As}{\lambda}\ e^{-h/\lambda} & 0.0I < h < 0.25\ m \end{cases} \qquad (I)$$

where $q(h)$ - the volumetrical soil activity on the depth h, Bq/m^3 ;

A_s-Cs - isotope contamination density, Bq/m^3 ;

h_o - 0.0I meter;

λ - migration depth, m.

Depth of migration depends on physico-chemical properties of the radioactive fallout, soil type, humidity and some other factors and is about I.3 cm, average. This may lead to the dose rate attenuation of approximately 2 times, compared with surface activity distribution. Comparison with data, obtained in autumn I986, shows that after the spring freshet of I987, there was no sufficient migration of Cs-radionuclides. It was also noted that migration of other nuclides, particularly of Ru-I06, had a higher rate.

The important characteristic of the gamma-radiation field is the energy composition of the direct and dispersed gamma-radiation out- and indoors. Relative percentage of some energy groups into the dose rate in summer I987 is presented in Table I.

Attenuation factor for gamma-rays with actual energy composition was 2.I for timber and 8 for concrete buildings.

First-year external dose assessment for the population inhabiting the contaminated areas permanently, can be estimated by the empiric relationship:

$$D_I = k\ A_s\ (Cs\text{-}I37) \qquad (2)$$

where D_I - irradiation dose, Gy;

A_s (Cs-I37) - surface contamination density, Ci/km^2 ;

k - empiric factor, presented in Table 2.

Table 1. Relative contribution of the different energy ranges into the gamma dose rate.

Measurement place	Different energy group contribution into the gamma dose rate							Average gamma-ray energy, keV
	0-150 keV	150-300 keV	300-450 keV	450-600 keV	600-750 keV	750-900 keV	900-1050 keV	
Inside milk farm	8.7	22.9	12.3	14.5	27.8	11.9	2.0	0.28
Territory aside milk farm	7.6	19.5	10.7	17.0	31.6	12.2	1.5	0.30
Inside timber house	12.3	24.1	14.4	16.4	22.4	9.2	1.3	0.24
Inside concrete house	13.1	27.4	15.0	14.7	18.7	8.8	2.4	0.23
In the private yard	7.9	18.5	10.9	16.8	32.0	12.7	1.5	0.30
Forest	5.0	15.0	9.1	15.0	38.1	15.7	2.1	0.36
Meadow	5.0	14.4	8.9	13.8	38.4	17.2	2.4	0.37
Arable land	9.5	22.1	13.1	14.3	27.1	12.3	1.7	0.27

Table 2. Empiric coefficients for external dose assessment

Region :	Bragin	Narovlja	Khojniky Kormjansk	Vetkovo Chechersk	Novozybkovo
$K \cdot 10^{-3}$	1.8 E-3	1.1 E-3	1.5 E-3	0.9 E-3	0.8 E-3

It is noteworthy, that at least 70% of individual doses are less than above estimated.

Second-year dose is assessed as follows:

$$D = 3.6 \cdot 10^{-3} \quad P \qquad (3)$$

where D - the second-year dose, Gy;

P - dose rate on 1 June 1987, mR/h.

At least for 90% individuals, doses are less than this value.

Significant effect was obtained due to decontaminating works, conducted in 1986-1987. Decontamination was conducted on the territoties of kindergartens and hospitals, other social and industrial buildings and houses by means of removing the most contaminated places with further covering with sand, gravel and partially with asphalt. Large works on decontamination of street and roads, dust suppression, modernization of settlements were being conducted. In Table 3 is presented the ratio: dose rate in different zones inside the settlement after the decontamination dose rate over meadows, characterizing the primary contamination.

Table 3. Dose rate reduction in settlements after the decontamination.

Zone	Object	P decont./ P meadow	
		June 1987	September 1987
Living	In-doors	0.34	0.28
	Yard	0.69	0.74
	Kitchen-garden	0.74	0.74
Public	Street	0.72	0.35
	School, kindergarten		
	In-doors	0.09	0.08
	Yard	0.40	0.40
	Hospital		
	Office		
	In-doors	0.13	0.14
	Club		
	Yard	0.66	0.47
	Shop		
Industrial	Milk farm		
	In-doors	0.26	0.52
	Yard	0.67	0.64
	Garage yard	0.65	0.30
Area	Meadow	1.00	1.00
	Arable land	0.70	0.70
	Forest	1.07	1.04

It follows from Table 3, that the maximum dose rate reduction was achieved on the territories of school yards, kindergartens and other social places. Conducted decontamination measures allowed to decrease the dose, compared with expected dose, I.3-2.5 times for different professional and age groups of population; the maximum reduction was noted for children. On Fig. IO relative level of average doses for different professional and age groups in the same settlement is shown; data was obtained by personal dosimetry. Obviously, the critical groups are the forestry workers and farmers; thier life regime is connected with the maximum time spent outdoors on the non-decontaminated territory of the settlement in-

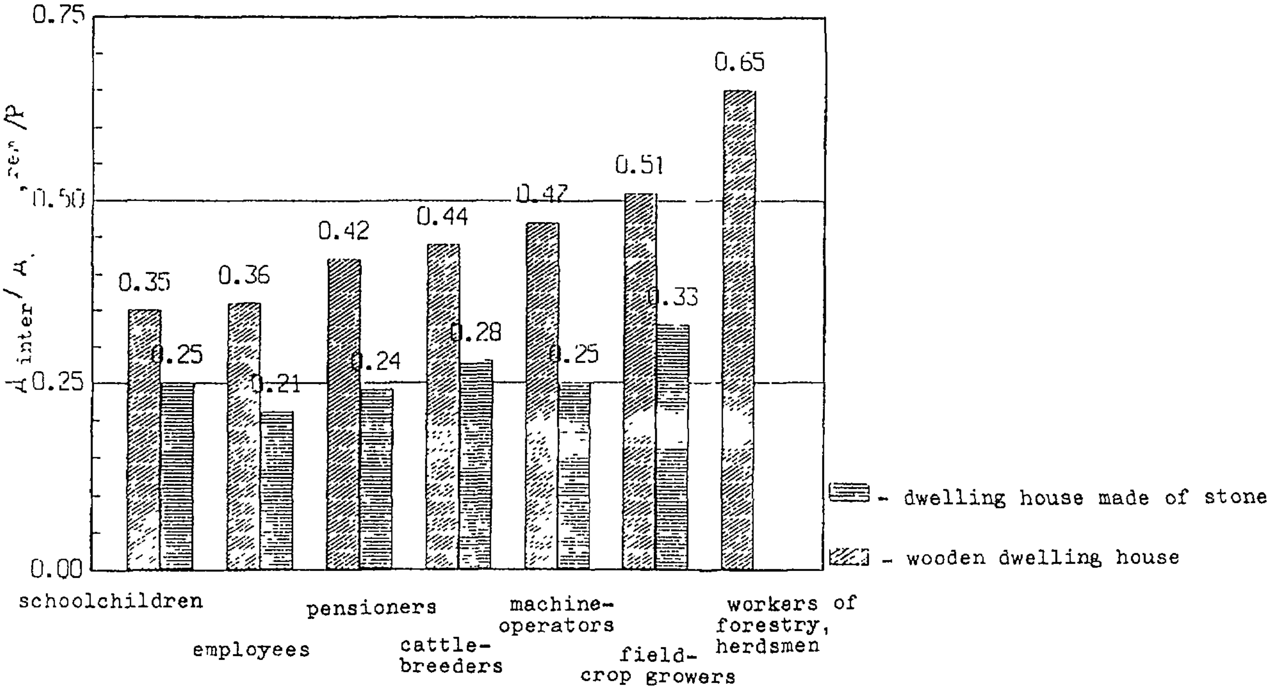


Fig.IO. Ratio of dose of rural population external exposure to gamma dose in the open area for different professional and age groups (May-September I987).

dustrial area. However dose loads on the critical contingent does not exceed forecast assessments, given during the stage of developing of the protective measures for population radiological security.

Thus, it may be concluded, that the whole complex of experimental data concerning external irradiation control confirmed correctness and timeliness of operative and long-term radiological situation forecasts and proper decisions.

MONITORING OF INTERNAL EXPOSURE OF THE POPULATION IN REGIONS CLOSE TO THE CHERNOBYL NUCLEAR POWER PLANT

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I.G. ZHAKOV, B.A. LEDOSHCHUK, P.V. RAMZAEV

Abstract

In the first month and a half after the accident, the dose burden on the population was determined by radioactive iodine deposited in the thyroid gland. Later, the dose burden was governed by caesium-134 and caesium-137. The measurements made are generally reliable. Departures from the norm in extreme cases (in the event of marked differences from the standard body build) were no more than 50% of the actual activity (at levels above 150-200 nCi).

Since there is no effective method of measuring nuclides incorporated into the bodies of children, it is necessary to develop special phantoms simulating the human body at different ages.

As a result of the Chernobyl accident a large ammount of various radionuclides were released into environment. During the first I,5 months after the accident the main population loads were determined by radioiodine uptaken by thyroid gland. Practical task on the assessment of thyroid irradiation was being solved by determination of ^{131}I in this organ that may be considered as a point source.

Broad application of thyroid function radioisotope diagnosis as well as other radiometers, at a correct organization of the works, allowed to obtain ample data about thyroid irradiation in the population of near-site regions.

Specialized spectrometers (counters) of whole body (WBC) were used in a number of areas of our country during the accident period and later. The necessity of prompt estimation of ^{134}Cs and ^{137}Cs in significant contingents led to transfer of transportable WBCs into the regions of examination as well as to the usage of medical radiodiagnostical equipment from radiological departments of clinics and research institutes, SRP radiometers (instrument, used for geological survey) and single-channel counters with scintillation detectors of various type. Several hundreds of operators, who had had little idea about specificity of incorporate radioactive mixture measurements, were urgently trained and involved into the works.

The questions of graduation of the instruments were solved in different ways and were the most acute ones, as metrological support of these estimations in the field of dosimetry was insufficient.

Application of various types of equipment for measurements of incorporate radionuclide content in human body, necessitated verification of data obtained in 1986 and 1988.

In contrast to internal irradiation control on enterprises, the actual situation urged to examine population contingents of different age groups, including newborns. That is why in our study we had to use fantoms of youngest children (2-3 years old), teenagers (10 - 14 yers) and adults.

Character of cesium radionuclides irradiation was taken into account during the study. ^{137}Cs is monoenergetic gamma-radiator with the energy (output) 661,6 keV (84,6%), and ^{134}Cs has basic lines 569,4 (16%), 604,7 (98%), 795,8 (86%), 801,9 (8,7%). The measurements showed, that there were no other nuclides beside the mentioned ones in the examined individuals (semiconductor detector control).

Gamma-lines of ^{134}Cs (569 and 605 keV) are not resoluted by scintillation detectors with cesium line of 662 keV. At the actual situation of contamination the process of identification was hampered by ^{95}Zr and ^{95}Nb contributions (usually clothes contamination). Division of instrument gamma-line, consisting of lines 605 keV (^{134}Cs) and 662 keV (^{137}Cs) into its structural parts led to the errors due to the vagueness of pedestal form under these lines in cesium isotope sum spectrum. The majority of instruments, like earlier, in our situation were graduated by ^{137}Cs, and the transition to graduation coefficient for cesium isotope sum was made with the help of calculated or empiric factor.

Therefore, volumetric sources (4 jerrycans with ^{134}Cs) were used. They were measured in identical geometry with analogous sources of ^{137}Cs. Thus was estimated graduation factor for ^{134}Cs and ^{137}Cs. These nuclide ratio was assumed to be I:2 for ^{137}Cs (according to precision gamma-spectrometry). Table I gives the main fantom parameters, filled with water solution of ^{137}Cs, used for calibration.

Table I. Fantom parameters

Fantom	Immitated age, years	Height, cm	Weight, kg	Median thickness, cm	^{137}Cs activity, Ci
FR	2	84	II,6	8,2	I,II5
FV	I7	I70	70	I4,2	I,89
FP	I0	I3I	27,6	I0,2	2,755

Common feature of all the used instruments is registration of cesium isotopes gamma-irradiation by scintillation detectors. These detectors were in all the cases but one, Tl-activated sodium iodide crystals of different size: from 20 x 20 mm to 203 x I02 mm. In one case organic scintillating plastic was used as a detector.

In eight instruments multichannel amplitude analysers were used. However, due to the above mentioned irresolubility by scintillation detectors of gamma-lines of ^{134}Cs and ^{137}Cs, and laboriousness of spectrum hand-processing, imperfection of software, all the spectrometers work in the regime of summary gamma-activity measurement. These measurements are conducted in one or two energy windows under visual control of operator.

The rest of the instruments may be considered body monitors, using spectrometry qualities of detectors and registring gamma-irradiation in this or that window selectively, without visual control. Table 2 gives main technical characteristics of the mentioned spectrometers, plus stationary instruments for radioisotope diagnosis (gamma-chambers Fo-gamma and gamma-chronograph RIH-5M), which in 1986 were temporarily adopted for incorporate cesium measurements. The minimum time of measurements (10 s) has "Quick Body Monitor", the average time is 60 s, and the maximum - 600 s.

Table 2. Main technical characteristics of whole body counters

Type of monitor	Geometry of measurements	Detector size, mm^2	number	Type of pulse analyser
WBM I.I	Fixed chair	I50xI00	I	Nokia 4840
WBM 2.2	"	203xI02	I	Nokia 4900B
WBM 2.5	"	63x63	I	Nokia 4840
WBM 5.6	Scanning	I50xI00	4	Nokia 4900
WBM-K	Fixed chair	63x63	I	AI-I024-95
SWBMChZch80	Scanning	63x63	2	AI-I024-95
RIX-5M	Couch, H=I,4 m	63x63	I	Singlechannel
LFO-IV	Couch, H=0,45 m	400	I	Singlechannel
QBM-I	Sitting	282000	2	Singlechannel
FO-gamma	Couch, H=0,45 m	260x8	I	Singlechannel
SSR	Couch	500x400x20	2	Singlechannel
WHB-3-I	Fixed chair	I50xI20	I	Nokia 4840
WBM-0-4	Scanning	I50xI00	4	Nokia 4900

All the mentioned instruments can be divided into 5 groups according to the applied geometry:

I. Examined subject is sitting in an arm-chair in front of detector. This geometry has the property of autocompensation of adult body thickness.

2. Iso-sensitive geometry of longitudinal scannind by a detector pair on the top and bottom of the subject.

3. The examined subject lies under the detector on a straight couch.

4. The examined is sitting on a chain between two detector blocks.

5. Measurements in the so-called "North" geometry, when the subject is sitting on a chair with his feet on a pedestal I5 cm high, his torso is put foreward , and detector is set against its lower part. At this geometry a body a sort of surrounds detector and at even distribution of radionuclides in the body this method gives only insignificant errors.

The instruments were graduated by both total body activity (in this case was given a number of graduation factors for different ages), and by activity concentration per 1kg of body weight.

Table 3 gives the main operational characteristics of the used instruments. It is clear that minimum detectable activity differ significantly, depending on the type of instrument: from several nCi (fixed instruments) to 20-I00 nCi (mobile instruments). We know that the balance of I00nCi in the body during the year forms the dose of 30-40mrem/year for a given mixture of radionuclides for an adult, i.e. one fourth of background dose.
Table 4 shows the results of study of simplest radiometre characteristics, which were used for incorporated cesium measurements. The measurements were performed with the help of two investigators who had taken the measured quantity of radio-cesium. The results show that measurements with the simplest radiometers (minimum detectable activity about 500 nCi) are quite reliable.

Table 3. Operational characteristics of whole body monitors.

Type	Gamma-dose rate, μR/h		Instrument background, pulse/s	MDA, nCi	Characteristics			Error, %
	out of doors	in-doors			FR	FP	FV	
WBM-I-I			3,49	6	I,09	I,04	0,9I	6
WBM-2-2			0,72	I	I,34	I,05	0,97	6
WBM 2,5	25	20	I,9	20	0,89	0,65	I,II	9
WBM 5,6M			II,6	5	I,oo	I,oo	0,98	6
WBM-K	I50	25	I4,5	70	I,I9	I,02	0,87	II
SWBMChZch80	I50	22	2,6	90	0,9I	0,9I	0,86	I0
FO-gamma	I50	28	I0,7	50	0,92	0,95	I,36	I2
LFO-IV	I50	20	34,5	I00	0,77	0,73	0,87	8
RIX-5M	250	30	3I,2	I000	I,34	I,35	I,07	75
QBM-I				30	I,49	0,89	0,72	
SSR	I5	I5	24,2	35	I,29	I,II	I,02	9
WBM 3.I	I5	I5	0,62	4	0,97	0,83	0,80	8
WBM-0-4	I5	I5	6,4	3	0,96	0,80	I,o	7

Table 4. Results of selective radiometre tests.

Type of instrument	Tester	Graduation factor	Background	Results of measurements
SRP	I.I	$5,5\cdot IO^{-4}\ \frac{\mu Ci\ h}{\mu R\ kg}$	40 R h	0,9
	I.2	"	"	0,75
RGT	I.I	$0,59\cdot IO^{-3}\ \frac{\mu Ci\ h}{\mu R\ kg}$	73 pulse s	0,85
Robotron	I.2	$I,2\cdot IO^{-4}\ \frac{\mu Ci\ IOOs}{kg\ pulse}$	I,6 pulse s	I
GTRM-0I	I.I	$2,I\cdot IO^{-3}\ \frac{\mu Ci\ min}{pulse}$	2,5 pulse s	I
NK-350-A	I.I	"	4,2 pulse s	I,08

Conclusions:

I. The results of cesium isotopes mixture measurements in human body are reliable. Deviations in extreme cases (an unstandard figire)could be no more than 50% of real activity (at the levels of no more than I50-200 nCi).

2. In I986 in the USSR there, unfortunately, was no sufficient ammount of instruments for incorporate activity measurements. That had led to additional effort for daptation of various medical instruments for the study.

3. The fact of absence of special methods of incorporate nuclide measurements in children urges the development of human body fantoms for different ages.

METHODS FOR RETROSPECTIVE DETERMINATION OF ABSORBED DOSES IN THE HUMAN BODY RESULTING FROM EXTERNAL AND INTERNAL EXPOSURE

M.I. BALONOV, I.B. KEIRIM-MARKUS,
U.Ya. MARGULIS, D.P. OSANOV

Abstract

In order to estimate the absorbed dose to surface tissues in people working in a contaminated area, a calculation method has been developed based on area integration of the modified response function for a point beta-gamma source. Practical testing of the method in real conditions confirmed its usefulness for prognostic evaluations.

The main contribution to the dose is made by beta radiation with a limiting energy of 1.0-3.5 MeV and by gamma radiation with an effective energy of 20 KeV.

The population centres studied were divided into towns and villages and the inhabitants were divided into seven age groups.

Preliminary data from an analysis of the radiation burden of the population in regions adjacent to the Chernobyl power plant zone show that the evacuation of the population from the 30-km zone and other steps taken to organize living arrangements in these regions brought about a radical drop in the levels of population exposure.

The issue of retrospective estimation of a dose burden acquires particular importance in the event of accidental or accident-induced human exposures, when information on the level of radiation effects is essential for taking organizational and medical measures aimed at minimizing the consequences of exposure and normalizing the situation. In the case of acute exposure, even if persons injured had personal dosimeters, it is sometimes needed to reconstruct distribution of dose burden on a body exposed to external irradiation. Ingestion of radioactive substances in substantial quantities may necessitate prompt determination of their body content and distribution.

If during an accident or radiation incident, dosimetric monitoring was lacking or proved insufficient, the task of reconstructing dose burden becomes much more complicated, though it is not hopeless. If no personal dosimeters are available, the human dose burden induced by external irradiation not infrequently can be determined by techniques of dosimetry without dosimeters. Specifically, it can be done using traces left by irradiation in materials. In numerous cases there are formed free long-lived radicals, whose concentrations can be measured later. In fact, in 1973 an attempt was made to reconstruct the doses received by humans killed during atomic bombardment in Japan. The researchers employed a signal of electron spin resonance (ESR) produced by specimens of skeleton bones. In I977 I.A.Alekhin, I.B.Keirim-Marcus, C.I.Kraitor et al. suggested to utilize radioluminescence (RL) for estimation of doses in specimens of hair, nails, skin and clothes of persons exposed to radiation during an accident. Subsequently, ESR technique was also employed in such cases.

To measure RL, the tissue specimens weighing IO-IOO g are submerged in a dish with appropriate solvent, and then luminescence produced by dissolution of a sample is estimated by PEM. In order to determine ESR the specimens of the same weight are introduced into resonator of radiospectrometer, where ESR signal, dependent on presence of free radicals in a sample, is measured.

The measurements performed showed that sensitivity of techniques is influenced by a level of a background signal, and ESR technique appears more sensitive than RL. In radiospectrometers employed, the minimal dose, registered for specimens of white cotton fabric equalled about I Gy. For other fabrics of clothes, hair and protein-based biological samples the dose appeared 3-I5 fold higher and sensitivity was, correspondingly, lower.

Following irradiation, free radicals gradually disappear, particularly in protein-based specimens. However, the doses can be determined even after a long post-accident period, as it happened in the case of P. While recharging a radiation source Luch-I he failed to notice that a gate of output window in container with a source I.5 X 10^{14} Bq ^{60}Co remained open. A beam of gamma radiation affected the mid-portion of his thighs. Only 4 months later P. referred to a specialized clinic, where examination revealed radiation injury of the lower extremities. The ESR and RL study of material of the trousers which P. wore that day enabled researchers to reconstruct the topography of dose along perimeter of thighs. After making a correction for reduced level of radicals in the material with $T_{I/2}$ = 2 mon, the dose maximal values on posterior surfaces of the thighs were measured and they equalled 52±IO Gy on the right leg and 40±IO Gy on the left. Certain experience has been already accumulated in applying the above techniques in similar cases.

Since radioactive contamination of all patients was very high the efforts to determine a level of irradiation by clothes also ended in failure. Then technique of dosimetry without dosimeters was utilized. This technique is based on measuring ESR signal from enamel and was employed in I984 in Japan for retrospective estimating the level of exposure in atomic bombardment victims. Later this method has been modified and improved. In our institute E.D.Kleshchenko and K.K.Kushnereva have mastered this method and with its aid they measured in June of I986 the dose rate in three patients who had died from the radiation sickness. The estimated values 6; 6 and II±2 Gy correlated with severity of injury.

Since ESR signal from enamel seems to be preserved fairly well and allows estimation of doses starting from O.I Gy, this technique appears rather promising in reconstructing the volume of dose burden for the period of occupational activity of the persons examined.

It should be pointed out that in the initial period after the accident at CNPP, the persons enrolled in management of its consequences in buildings and on the construction site, developed reddening of skin ("nuclear sunburn"), sensation of burning (irritation) of eyes, caused by intensive beta- and low-energy gamma radiation impact on superficial and, particularly, open areas of the body. The necessity arose to clarify contribution of these components into the dose absorbed, and to determine effective energy of actual radiation. It was also mandatory to develop a procedure on the basis of radiometric and spectrometric data for measuring the dose in skin of persons staying in contaminated area.

To disclose distribution of absorbed doses in skin, the use was made of multilayer thermoluminescent dosimeters designed by D.P.Osanov and A.I.Shax. Effective energy of emitted radiation was evaluated by measuring depth dose distribution by sets of thin-layer detectors, placed in tissue-equivalent containers.

Major contribution to this dose is made by beta-radiation with boundary energy ranging I.0 to 3.5 Mev and gamma-radiation with effective energy 20 KeV, which cannot be measured by standard personal dosimeters.

Individual doses in skin were measured in persons engaged in decontamination of the NPP territory, construction site and buildings, and also in personnel repairing mobile facilities, etc. The results obtained showed that dose of beta-radiation in skin, measured in conformity with SRS-76/87 in a layer IOO mg/cm^2 after a layer 7 mg/cm^2, in multiple cases was found to be 6 fold higher than individual dose of gamma-radiation determined by standard dosimeters. This is indicative of the fact, that in a number of cases skin was exposed to overdoses and appeared a critical organ.

Proportion of dose, accumulated in the lens is approximately 2-3 times higher than the dose of external gamma-radiation. These findings provided the basis for introducing additional measures of personnel protection.

To assess the dose, absorbed by body superficial tissues of persons working on contaminated territory, V.P.Kryuchkov and D.P.Osanov have developed a measurement procedure based on area integration of modified function of impacts of beta-, gamma-radiation point source. Testing of the procedure under real conditions (city of Pripyat) confirmed the feasibility of its applying for prognostic assessment. This procedure was utilized for estimating the absorbed dose in the skin of personnel involved in management of the accident consequences and in other kinds of work on the contaminated territory. The derived results suggest that in situations arising in a post-accident period, which are similar by their character to that observable after the accident at CNPP, the doses in organs and tissues located close to the surface can sometimes exceed in dozens of times the equivalent absorbed doses in depth of human body. This circumstance implies the necessity of including beta-radiation dosimeters into IDC emergency system supplementing it with measures aimed at protecting the body open areas and eyes from impact of beta- and low-energy gamma-radiation.

At the first stage after the accident at CNPP (approximately till the end of May, 1986), iodine radionuclides appeared the major factor responsible for internal irradiation of population, living on the territory affected by radioactive contamination. These nuclides could be inhaled from a passing plume (inhalation pathway) or ingested with milk and dairy products of dairy-productive cattle grazing on pastures in a contaminated zone, or they could be comsumed with contaminated from outside vegetables and other food items (oral pathway).

The above circumstances influenced the scope and trends in dosimetric and medical survey of population. Medical teams from the Ministry of Public Health of the USSR measured thyroid content of radioactive iodine in a large contingent evacuated beyond the 30 km zone and also in residents of some populated areas in the UkrSSR, BSSR, RSFSR, where radiation levels were found to be increased, though it was unnecessary to take decision on evacuation of residents. Particular attention was given to pediatric contingent, assigned to a group of increased radiation risk.

To avoid any delay in mass surveillance of population, the body content of radioactive ^{131}I was measured predominantly by simple techniques, i.e. by determining gamma-radiation exposure dose rate at the neck surface, employing for this purpose serial dosimeters and radiometers DRG, SRP, and DP-5. Data of phantom spectrometry were used in estimating a scaling ratio of the measured gamma-radiation exposure dose rate to ^{131}I thyroid content.

For inhalation pathway of exposure an equivalent absorbed dose induced in the thyroid by beta-radiation of iodine till its complete elimination, was measured according to routine formulae, based on data of individual measurements of dose rate, and, therefore, it presented no difficulties. While assessing dose burden, a correction was made for presence of airborne iodine radioisotopes, other than ^{131}I, depending on length of the post-accident period. According to V.T.Khrushch et al the inhalation route of exposure to radioactive contaminants predominated for residents of Pripyat and large cities, where the ingestion of contaminated food was ruled out. As regards the population living on the territory with the formed radioactive trace, even within a relatively short period of time (till evacuation beyond the boundaries of 30-km zone), the principal component of total absorbed dose in the thyroid was ^{131}I, ingested orally mostly with milk. This is confirmed by the observation that the level of thyroid exposure in rural contingents with low proportion of milk in their diet never exceeded 30 % even by excessive values.

For retrospective assessment of dose burdens after oral intake, in addition to estimated thyroid iodine content, it is also mandatory to be aware of ancillary input parameters, exerting substantial influence on final value of total individual dose in the thyroid: e.g. length of stay in contaminated territory, date when cattle grazing began, duration of consumption of dairy products. To solve this problem the calculation formulae were developed on the bases of the following assumptions: (V.T.Khrushch, Yu.I.Gavrilin, Z.S.Arephyeva)

- milk and dairy products were consumed only till the moment when thyroid radiation content was measured;

- consumption of milk and dairy products continued after measuring thyroid iodine content;

- consumption of milk received from cattle grazing on contaminated territory was stopped on certain dates prior to measuring thyroid radioiodine content;

- consumption of milk and dairy products was started following a certain period of cattle grazing on contaminated pasture and was ceased immediately after completing measurements;

- consumption of milk and dairy products was started following a certain period of cattle grazing on contaminated pastures and was not stopped after estimation of thyroid iodine content.

The choice of a suitable model for calculation of thyroid dose for every individual resident was made on the basis of data, provided by local sanitary epidemiologic stations and local authorities. The data were also supplemented with results of interviews.

To simplify calculations, the numerical values of parameters were tabulated. These parameters are used in each calculation model for varying time intervals between the beginning and the end of consumption of dairy products and milk, grazing of cattle on pastures, and dates when thyroid iodine content was measured.

Calculation of these parameters was based on characteristic of rate of ^{131}I intake with cow milk following single contamination of pasture, with varying patterns of grass and vegetable cleaning from iodine λ (0.1 to 0.3 day^{-1}) and decreasing ^{131}I content in milk γ (from 0.8 to 0.37 day^{-1}), which were selected in conformity with these λ values, providing the additional conditions are satisfied, that ^{131}I maximal concentrations in cow milk are always reached after 3 days of cattle grazing.

Large sizes of contaminated area did not allow researchers to measure iodine content in all residents during May. The task of retrospective appraisal of thyroid dose in this contingent emerged in the course of mass health examination of population in the autumn of 1986. The values of mean and individual doses were assessed in the first place, by comparing results of interviews with non-examined persons and residents with estimated iodine content in the thyroid, supplementing them with data on radioactive composition of fall-outs in this area, external gamma-radiation exposure dose rate, concentration in milk, age-related distribution of dose in surveyed residents of this region, including also social factors.

The surveyed populated areas were devided into rural and urban, and their residents were assigned to 7 age groups: under 1 year, 1-3 years, 3-6 years, 6-11 years, 11-15 years, 15-18 years and over 18 years. Within a homogenous age group in majority of populated areas the distribution of residents with respect to thyroid dose was close to lognormal. We have received weighted-mean by number of persons examined relationships between dose in various age groups and dose in adults, obtained in 6 cities and 12 villages of the RSFSR. These results suggest that influence of age on absorbed dose is more pronounced in urban areas than in rural ones. Probably, this may be attributed to relatively higher consumption of milk by adults and adolescents in rural areas than in cities, since they have their own cows. Utilizing mean relationships of doses in various age groups it becomes possible to estimate a mean dose received by residents of any age, if thyroid radiometry was carried out in one age group within population of the given city or village.

To extrapolate dosimetric data to rural residents, where in May 1986 radiometry was not performed, there was explored a correlation of dose, with ^{131}I concentration in consumed milk and with gamma-radiation exposure dose rate in the vicinity of settlements located in zones, used for cattle grazing. According to data of I.A.Zvonova (oral communication), both correlations appeared statistically significant. For the territories covered by iodine prophylaxis the following linear regression equations were derived:

$$\bar{D}\ (1\text{-}7\ yr) = 5.6\ \bar{C}_m\ (D+10 \div D+20),\ Sv$$

$$\bar{D}\ (1\text{-}7\ yr) = 1.9\ R(D+15),\ Sv$$

where $\bar{D}(1\text{-}7\ yr)$ - mean thyroid dose for pediatric contingent aged 1-7 years, $\bar{C}_m\ (D+10 \div D+20)$, MBq/l - mean concentration of ^{131}I in milk within 10-20 days after the accident; P(D+15), MR/hr gamma-radiation mean level in the areas close to settlements 15 days after the accident.

If data on thyroid radionuclide content are lacking, the individual dose can be estimated with the accuracy acceptable for goals of prophylactic examination by mean dose for residents of corresponding age in the given populated area with similar behavior patterns and dietary habits after the accident.

When such comparison cannot be made then a concrete person or a group of persons with lacking data on direct measurement of I^{131} thyroid content may be regarded as exposed to mean individual dose, characteristic of persons, living on that territory or on the territory with similar level of contamination by iodine radionuclides (iodine level in milk). In each concrete person the value of mean individual dose can differ severalfold from the actual one. To make assessment of individual dose value more accurate, there can be utilized data on average daily consumption of locally produced milk and mean time period of its actual consumption by residents of the given populated area. Value of dose burden D(Sv) assigned to a given individual can be calculated by relation:

$$D = \bar{D}\,[I - b(\frac{V}{\bar{V}} \cdot \frac{\theta}{\bar{\theta}})],$$

where $\bar{D}$ - mean dose for residents of the given settlement (or of the territory with similar contamination patterns), rad,

V - average-daily individual consumption of locally produced milk in April-May 1986 till its consumption was actually stopped, l/day; $\bar{V}$ - locally produced milk mean consumption by persons living on territory of the given individual's residence, or on territories with similar contamination patterns, l/day; θ - average daily individual length of locally produced milk consumption, days; b - mean proportion of radioiodine ingested with milk, $\bar{\theta}$ - mean length of locally produced milk actual consumption by persons living on the territory of individual's residence or on other areas with similar contamination patterns, days; $I-b$ - mean proportion of radioiodine intake by body through other pathways (inhalation, injested with vegetables, etc).

Statistical analysis of thyroid radiometric data and results of interviews with over 3000 residents of Bryansk region, made by G.Yu. Bruk and N.F.Korelina revealed that for RSFSR districts contaminated with radioactive products $b = 0.8$. For other regions coefficient b and $I-b$ were ascertained on the basis of field studies. If length of milk θ and $\bar{\theta}$ consumption exceeded 20 days, it should be regarded as equalling 20 days.

Models for calculation of individual doses in the thyroid under various conditions of population's everyday activities on contaminated territories and its consumption of dairy products, as well as the necessary tabulated material with numerical values of parameters, used in formulae, are described in "Manual for estimating thyroid radiation dose in radioactive iodine isotope intake by human body"(Ed. by L.A.Ilyin, academician of the USSR AMS).

Another possibility to assess individual dose accumulated in the thyroid is based on a correlation between ^{131}I intake by the body and its cesium content measured on later dates, for instance, in August-September 1986. Statistically significant linear relations (r = 0,7-0.9) between body iodine and cesium content is found for children older than 7 years and adults, who in May 1986, on the whole, stopped consuming locally produced food items and observed these restraints throughout the summer. In this case dose D (Sv) induced by radiation in the thyroid could be estimated from the formula:

$$D = k(T)A_{Cs}$$

where $k(T)$ - age-dependent coefficient.

Reconstruction of thyroid individual doses by these techniques is of limited accuracy. Nevertheless, selection of groups for medical follow-up, carried out on its basis, makes it possible to derive considerably more precise characteristics, than those obtained by utilizing mean values for this district or settlement.

Radioactive cesium appears an essential factor of population internal exposure in a zone of radioactive contamination. Since isotopes of both ^{137}Cs and ^{134}Cs released into the environment have large half-life periods and are retained in human body for a long time, it became possible in summer-autumn of 1986 to estimate by efficient techniques the content of these nuclides in a large population involving over 100 thousand residents. This work was continued in 1987 as well. Individual and collective doses of internal exposure were assessed by findings of a single or multiple radiometry. Scheme of such calculations should include a function of radiocesium intake after the accident. I.A.Likhtarev, Yu.O.Konstantinov, V.S.Repin have suggested to approximate the dynamics of radiocesium intake by a two-step function. The first step having large amplitude and lastng for about a month implicates ingestion of cesium with milk, meat, early vegetables in May 1986, prior to imposing rigid restrictions on consumption of local products. The second step with smaller amplitude reflects continuing chronic incorporation of small quantities of both radioisotopes together with food. Amplitude ratio for each district was determined on the basis of data on radiation monitoring of food items. In fact, for the Ukraine as a whole, the ratio of 1st and 2nd steps was taken as 2:1. This calculation scheme also took into account evacuation of some residents beyond the zone of intensive radioactive contamination. The calculations utilized values of radiocesium half-life in the body $T_{1/2}$, which were obtained by O.V.Lebedev and co-workers in long-term, WBC-aided surveillance of the residents, evacuated from a radio-contaminated zone in May 1986.

Practical application of the abovedescribed techniques for retrospective estimation of absorbed radiation doses in humans exposed to radiation effects following the accident at CNPP provided the possibility to classify the involved population contingents in terms of radiation level, and proceeding from the data derived, to institute sanitary-hygienic and organizational measures directed towards normalizing the situation and minimizing the radiation impacts.

Preliminary analysis of population exposure in the areas close to the ONPP zone shows that evacuation of residents beyond the limits of 30-km zone supplemented with measures introduced to govern behaviour and everyday activities of population ensure dramatic decrease in levels of population irradiation.

LONG TERM PROGNOSIS OF INDIVIDUAL AND COLLECTIVE EXPOSURE DOSES TO THE POPULATION

O.A. PAVLOVSKIJ

Abstract

For the purpose of evaluating the long-term consequences of radiation contamination following the Chernobyl accident, it was decided to divide the whole of the Soviet Union into a number of regions. Calculations were made with a special software package.

The collective dose commitment to the country's population due to caesium isotopes will amount to 117 000 man-Sv, of which the first year accounted for about 27%. Thus, the main contribution to the aggregate dose will be made in the second and subsequent years, i.e., a period when the formation of dose burdens to the population can be effectively influenced by strict monitoring of agricultural products, agrotechnical measures in the contaminated area and even by a thoroughgoing reformation of the economy. Many of these measures have already been taken in the USSR.

On the whole, the average individual dose commitment to the country's population will be about 1.2 mSv, which, given an annual level of background radiation in the USSR of 1 mSv/year, adds only 2% to the natural background dose.

In view of all the measures taken, the main contribution to the population dose commitment comes from external gamma radiation from the radioactive products released during the accident - ?% - and about 38% from internal exposure resulting from the consumption of contaminated food products.

Due to specific circumstances which influenced the radiation situation in the Soviet Union following the Chernobyl accident (a prolonged release of gases and aerosols from the damaged reactor and variable meteorological conditions), nearly the entire territory of the country was contaminated to a certain extent. To assess the long-term radiological impact of the contamination, the territory of the Soviet Union was split into five regions:

1 - Byelorussia;

2 - Northern Ukraine, including the Cherkassy, Chernigov, Chernovtsy, Ivano-Frankovsk, Khmelnitsk, Kiev, Rovno, Ternopol, Transcarpathian, Vinnitsa, Volynsky, and Zhitomir regions;

3 - Central region of the Russian Soviet Federal Socialist Republic (RSFSR), including the Bryansk, Ivanovo, Kalinin, Kaluga, Kostroma, Moscow, Oryol, Ryazan, Smolensk, Tula, Vladimir, and Yaroslavl regions;

4 - Remaining European part of the Soviet Union with the Asian part of the Ural economic region;

5 - Asian part of the Soviet Union.

The population size and density, the number of newborns in 1986, the proportion of the urban population, and the area for each of the five regions are given in Table 1.

Table 1. The population size and area for the 5 regions of the Soviet Union*)

Region	Population size, 10^6	Newborns in 1986, 10^6	Urban population, relative size	Area, 10^6 km^2	Population density, persons per km^2
1	10.0	0.17	0.63	0.208	48.2
2	21.9	0.35	0.54	0.269	81.4
3	29.8	0.51	0.82	0.485	61.4
4	139.7	2.47	0.69	4.533	30.7
5	77.4	2.12	0.57	16.696	4.6
USSR	278.8	5.62	0.65	22.191	12.6

*) Figures as of 1986.

Because of great importance of the ingestion pathway, information on staple foodstuffs (grain, potatoes, vegetables, meat, milk) produced in each of the regions was analysed, and their averaged production per square kilometre was estimated (Table 2). Table 2 also gives data on per capita food production in the regions under consideration, to be compared with per capita consumption rates for 1986 averaged over the country /1/:

Meat	62.5	kg/year
Milk	332	l/year
Vegetables	103	kg/year
Potatoes	108	kg/year
Grain (bread)	133	kg/year

Table 2. The production of staple foodstuffs in the 5 regions of the Soviet Union*)

Agricultural produce	Region	Production		
		10^9 kg(l)	10^3 kg(l)/km^2	kg(l)/man
Milk	1	7.0	33.7	700
	2	11.8	43.8	537
	3	9.2	19.9	308
	4	54.5	12.0	390
	5	19.7	1.2	255
Meat	1	1.1	5.1	106
	2	1.9	7.0	86
	3	1.4	2.8	46
	4	9.9	2.2	71
	5	3.8	0.23	49
Vegetables	1	0.97	4.7	97
	2	2.73	10.1	125
	3	1.79	3.7	60
	4	17.5	3.9	125
	5	6.73	0.40	87
Potatoes	1	13.4	64.6	1340
	2	15.6	57.9	711
	3	10.9	22.5	367
	4	35.0	7.7	251
	5	12.3	0.73	158
Grain	1	7.0	33.9	703
	2	16.8	62.4	767
	3	10.2	21.0	342
	4	119.0	26.2	850
	5	57.0	3.4	737

*)Figures as of 1986.

A comparison suggests a marked redistribution of foodstuffs among the regions, which has only in part been taken into account at the present stage of predicting the radiological situation in the Soviet Union.

The input data used for the prediction related to:

- Variation in the gamma dose rate in each or most of the 160 administrative territorial units of the Soviet Union (regions, territories, autonomous and Soviet republic /2 /), according to the information of the State Committee on Hydrometeorology and the Sanitary and Epidemiological Service (SES) of the USSR Ministry of Health (regional and republican SES);
- External doses over different months in 1986 for each or most of the regions in the Soviet Union;
- Air concentrations of the total radioactive material and of individual radionuclides;
- Ground deposition densities of the total radioactive material and of individual radionuclides;
- ^{131}I and radiocaesium concentrations in milk, meat, and vegetables;
- Diet patterns in different republics and agriculture production in each of the 160 administrative territorial units;
- Variation in the overall population size and in both the rural and urban populations within the Soviet republics from 1950 to 1986;
- Global contamination levels of agricultural produce due to caesium and strontium isotopes over 1964-1986 within the regional and republican boundaries.

The calculations were made using a special package of programmes, the basic methodological principles and results being presented below.

1. External exposure during the cloud passage

The contribution of this pathway is insignificant. It may be seen from Table 3 that, for the country as a whole, gamma exposure from the plume makes up 1.3% of the total collective external dose. For areas close to the Chernobyl plant, it contributes up to 2% due to doses received by the evacuees from a 30-km zone around the plant. Whenever there was information on air concentration or time-integrated concentration, gamma doses from the plume were calculated with the convential procedure using dose conversion factors from /3/. With no such data available, the air concentration was derived from the ground deposition density values by means of relationships based on the Soviet and foreign scientists' findings on the Chernobyl accident. In the dose estimation, the indoor gamma shielding factor was assumed to be two for country houses and ten for cities. The proportion of the urban to rural populations was also taken into account for each of the 160 areas concerned.

Table 3. External exposure of the public from the plume and fallout

	Region					USSR
	1	2	3	4	5	
Plume						
Collective dose, 10^3 man·Sv	0.97	1.09	0.17	0.26	0.00	2.49
Average individual dose, mSv	0.097	0.050	0.006	0.002	0.000	0.009
Fallout						
Collective dose, 10^3 man·Sv	53.4	48.3	32.8	53.9	6.2	194.5
Average individual dose, mSv	5.33	2.20	1.10	0.39	0.08	0.70
^{137}Cs contribution,%	74	61	77	67	93	70

2. External exposure from deposited radionuclides

As shown by calculations, this pathway, like internal exposure due to intake of contaminated foods, is a major contributor to exposures, accounting for more than 50% of the total dose to the Soviet population over the first year after the accident and for almost 60% of the lifetime dose. In these calculations, the dose for the first month was assumed to be determined by a mixture of radionuclides whose gamma dose rate decreased following the power law, with an exponent close to 0.75. For longer periods, the dose rate was assumed to be associated only with ^{134}Cs and ^{137}Cs and to change with time according to a biexponential dependence which describes a two-compartment model of the vertical migration of the above nuclides in the soil /4/. For ^{137}Cs, this corresponds to half-times of gamma dose rate reduction of three and 30 years, the "fast" and "slow" components being proportional to 0.6 and 0.4, respectively. With no data available on the ground deposition density of caesium isotopes, the relationships from /5/ were used. It should be noted that external exposure of the Soviet population in the first year after the accident constitutes 26.7% of the lifetime dose. Of this 26.7%, 20.2% is accounted for by ^{131}I and other short-lived isotopes and the remaining 6.5% is distributed almost equally (3.5% and 3%) between ^{134}Cs and ^{137}Cs. For the lifetime dose, the main part will naturally belong to ^{137}Cs whose contribution to the total external dose from deposited radionuclides varies with region from 60% to more than 90% and averages about 70% for the country as a whole (Table 3). When estimating short- and long-term exposures from ^{137}Cs, account was taken of variations in both the overall population size and the relative size of the urban population in individual regions of the country. It should be stressed that decontamination played an important role in reducing external gamma exposures, particularly in areas not far from the Chernobyl plant. The decontamination of more than 600 population centres, the removal and burial of contaminated soil, the suppression of dust over large areas, the asphalting or covering of contaminated sectors with gravel chippings, sand, or fresh earth, the designation of exclusion zones , the restrictions imposed on productive activity, and other similar measures enabled average public exposures in these regions to be reduced by a factor of two or three.

3. Internal exposure from inhalation

The contribution of this pathway is not considerable, the main part being played by ^{131}I. Calculations were made for a mixture of iodine isotopes, ^{132}Te, ^{134}Cs, and ^{137}Cs. Dose factors correlating the dose to the thyroid or other organs with a unit of intake were obtained from /6/. In the absence of direct measurements of air concentrations for ^{131}I, ^{134}Cs, and ^{137}Cs, these were estimated on the basis of the ground deposition density values. The calculations show intake by inhalation to account for about 3.5% of the total collective effective dose equivalent commitment for the country as whole, with region-dependent variations in a broad range (from 1.4% to 8.5%; see Table 4) due to specific climatic conditions and protective measures taken.

4. Internal exposure from ingestion

This pathway is the most "controllable", thus permitting changes in the dose commitment. Of the main isotopes contributing to exposures, ^{131}I, ^{134}Cs, and ^{137}Cs were chosen since they could be positively found, especially within the first months after the accident, in agricultural produce over the whole country.

Table 4. Effective dose equivalent commitments due to inhalation and ingestion

Intake	Region 1	2	3	4	5	USSR
Inhalation						
Collective dose, 10^3 man·Sv	1.50	1.09	0.80	1.06	0.01	4,46
Individual dose, mSv	0.15	0.050	0.027	0.008	0	0.016
Ingestion						
Collective dose, 10^3 man·Sv	50.5	30.2	8.7	35.0	0.72	125.1
Individual dose, mSv	5.04	1.38	0.29	0.25	0.01	0.45
^{131}I contribution,%	2.2	11.0	6.9	8.4	2.8	6.4
^{137}Cs contribution, %	80.5	72.3	63.2	73.9	80.6	75.5

^{131}I appeared in the milk of cows which grazed on pasture as early as two or three days after the accident. At that period, ^{131}I contamination of milk in southern Byelorussia, northern Ukraine, and the RSFSR regions adjoining the accident area amounted to 0.04–0.4 MBq/l, i.e. tens and even hundreds times as high as the established standard (3.7 kBq/l). However, milk from cows kept in stalls was far less contaminated. In each of the contaminated regions, hundreds of milk samples were analysed every day. This provided detailed information on changes in the contamination of agricultural produce both in individual regions and the country as a whole. An analysis of the data obtained confirmed the log-normal ^{131}I concentration distribution in milk and showed that the integral of ^{131}I concentration in milk put on sale through the centralized system was about 170 Bq·y/l for the Gomel region, about 230 Bq·y/l for the Mogilyov region (both in

Byelorussia), and 10, 100, or more times lower for other regions and republics. At the same time, e.g. on 17 May 1986, the ^{131}I concentration exceeded 3.7 kBq/l for 20-30% of milk in the above regions of Byelorussia. Due to the measures on milk control in the regions close to the Chernobyl plant, the ratio of the time-integrated ^{131}I concentration in milk on centralized sale to the ground deposition density proved to be 4-10 times lower than in regions with no measures taken. Accordingly, the ^{131}I contribution to the collective effective dose equivalent commitment from internal exposure averaged 6.4% for the country, varying from 2.2% to 11% for individual regions (Table 4).

The calculation of doses resulting from radiocaesium intake within the first year after the accident is similar to that given above for ^{131}I. To estimate intakes of caesium isotopes, data on contamination levels of milk, meat, and vegetables in all regions of the Soviet Union were used. It was shown that, with a geometric mean of the ratio of the ^{137}Cs concentration in milk (Bq/l) to the ground deposition density (kBq/m^2) of 21 for the country as a whole, the ratio in the most heavily contaminated regions was close to five for milk put on sale through the centralized system. The collective doses for the Soviet population due to ^{134}Cs and ^{137}Cs make up 13% and 20%, respectively, of the total dose over the first year after the accident.

To predict the immediate and late health effects of caesium isotopes seems to be more difficult. The coefficients for ^{137}Cs transfer to the main types of agricultural produce used in the present paper were obtained in 1964-1986 from analyses of the monitoring data on fallout contamination of the Soviet territory caused by nuclear tests. From these studies, the half-life of ^{137}Cs in milk was found to be 8.4 years for the Soviet Union, i.e. the "clean" soil component of the decontamination model for caesium as a chemical element is 0.06 year^{-1}. Accordingly, the integral intakes of ^{134}Cs and ^{137}Cs were assumed to be 2.5 and 12 fold intakes of these nuclides for the second year after the accident. The calculation of collective doses also allowed for growth in the populations of different regions of the country, but the diet pattern was taken to be the same as in 1986. The latter assumption may result in somewhat underestimated values since the clear trend in the Soviet Union in recent years has been for increased consumption of meat and dairy products and a rather marked decrease in the annual consumption of potatoes and bread.

The collective dose commitment for the Soviet population due to caesium isotopes is estimated to be 117 000 man•Sv, of which only about 27% is attributed to the first year. It follows that the main contribution to this dose will be made in the second and subsequent years after the accident, i.e. during a period when public exposures can be effectively regulated by strict control of foods and by agrotechnical measures on contaminated land, including even the restructuring of farms. The above measures, most of which are being implemented in the Soviet Union, have considerably reduced doses to the public, the average values for the first year in the most heavily contaminated areas of the Gomel Kiev, Bryansk, and Mogilyov regions being 10-15 mSv, with less than 50% caused by internal exposure from ^{134}Cs and ^{137}Cs. Only in 0.5-1% of those examined did internal doses exceed 50 mSv.

The per capita dose commitment for the Soviet population will total about 1.2 mSv which, given an annual natural radioactivity background of 1 mSv/year in the Soviet Union, only means an approximate 2% excess. This figure is about two or three times the dose received by the populations of Italy, Hungary, Sweden, and other western European countries affected by the release from Chernobyl /6-9/.

Allowing for all measures taken, the major contributor to the dose commitment for the Soviet population (see Table 5) is external gamma radiation from deposited fallout (about 60%), with about 38% being due to internal exposure from contaminated foodstuffs. It is noteworthy that, in those population centres where no protective measures were taken because of low absolute levels of radiation and food contamination, the ratio of internal to external exposures over the first year after the accident sometimes approached 10. Meanwhile, in all population centres where food was controlled and those foodstuffs which did not meet the established standards were rejected, the above ratio was close to 1.

Table 5. Collective and per capita effective dose equivalents for the first year and lifetime

Exposure pathway	Effective dose equivalent: collective, 10^3 man·Sv		Effective dose equivalent: per capita, μSv		Percentage	
	first year	lifetime	first year	life-time	first year	lifetime
Gamma radiation from cloud	2.49	2.49	8.9	8.9	2.52	0.76
Inhalation	4.46	4.46	16.0	16.0	4.51	1.37
Gamma radiation from fallout	32.0	194.5	187	698	52.6	59.6
Ingestion	39.9	125.1	143	449	40.4	38.3
Total	98.9	326.5	355	1171	100	100

It was shown that the complex of prophylactic and protective measures taken reduced individual external doses by a factor of two or three and internal doses to the public by a factor of 10 or more as compared with the values predicted. The agrotechnical as well as sanitary and hygienic measures to be taken in future are likely to reduce dose commitments for the populations of individual regions and of the Soviet Union as a whole as compared with the values given in Tables 4 and 5.

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DISCUSSION

A.J. GONZALEZ (IAEA)

One common theme of this afternoon discussion has benn the logic for establishing intervention levels after unanticipated situation involving radiation exposure has actually occured.

Following the Chernobyl accident there was a temptation, by various authorities, to link such intervention levels with the dose recommended for radiation protection planning for anticipated situation. There is not, however, any conceptual link between intervention levels and dose limits, as it was shown during the discussion, and it will be worthile to record this message since the confusion still exists in many places.

As you properly stated during the morning section, Mr.Chairman, the main logic for settling intervention levels is just common sence. Common sence for balancing the benefits expected from the intervention against the harm such intervention would unevoidably produce.

CLINICAL ASPECTS OF RADIATION EFFECTS

ACUTE EFFECTS OF RADIATION EXPOSURE FOLLOWING THE CHERNOBYL ACCIDENT: IMMEDIATE RESULTS OF RADIATION SICKNESS AND OUTCOME OF TREATMENT

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V.B. BOGUSLAVSKIJ, V.N. POKROVSKAYA

Abstract

The effect of penetrating radiation evenly distributed over the whole body was the main cause of the development of general clinical syndromes typical for the dose range 100-1600 rads (1-16 Gy): bone marrow, intestinal and transitional forms or combinations of these syndromes.

According to gamma spectrometric measurements of blood and urine samples and posthumous examination of organs and tissues, the maximum concentrations of radioactive iodine-131 in the body were 1-5 mCi (for various patients); for caesium-137 and 134 the figures were 2-2.5 mCi, and contamination by cerium-144 did not exceed 30 mCi (about 95% of cerium activity was in the lungs). Other nuclides did not exceed their MPCs.

For plant personnel on site at the time of the accident, the average exposure dose to the lungs was 0.2 Gy, to the thyroid gland 2.5 Gy, and to the whole body about 0.05 Gy.

A whole-body dose of 0.7 Gy may, as a general guide, be regarded as the minimum dose causing insignificant but consistent and individually significant changes in the blood picture which are characteristic of acute radiation sickness of the first degree. Variant 1 of a diagnostic programme designed to ensure a uniform approach to the diagnosis of first degree acute radiation sickness has been established.

Of 21 patients with acute radiation sickness of the third degree (dose range 4-6 Gy), 14 survived. All patients with acute radiation sickness of the fourth degree died except for one. Generally, death resulted from a combination of clinical syndromes, primarily the intestinal and bone marrow syndromes with total or subtotal skin damage.

Recovery of haemopoiesis was extremely active: in 84% of cases, the normal blood picture was re-established after 1 to 1 1/2 years.

Indicators of fitness for work returned after 8-9 weeks in patients with first and second degree acute radiation sickness and were high one year after exposure. Some who suffered acute radiation sickness are now working at the Chernobyl plant. Their doses in 1987 did not exceed 0.6 rem.

The information on conditions of irradiation and clinical records of acute radiation sickness (ARS) in victims of the Chernobyl NPP accident have been first reported to the IAEA experts in August I986 (I) and included in the report No. 25 INSAG IAEA (2).

Prognostic evaluations of the outcomes of the hemopoiesis injuries were given by A.K. Guskova and A.E. Baranov at the Conference of the Royal College of Patologists in Great Britain in April I987. Authors data are included in a special Annex of UNSCEAR Report on early effects of radiation, which should be finalized in I988 and presented to the Session of UN General Assembly. All the time further analysis in depth of the clinical aspects of situation earlier declared group of patients was going on. Some results of this analysis are presented below.

Earlier formulated opinion about the relative significance of the separate components of combined radiation influence (I,2) was fully confirmed by clinical-anatomical, labaratory and cardiological analysis as well as pathologically-anatomical and biophysical postmortem investigations.

Except for two patients (N24, 25), who had the combination of acute radiation sickness (ARS) and of thermal burns, all others were mainly affected by general whole-body uniform gamma-beta irradiation. The action of penetrating radiation on the whole-body was the main reason of the development of clinical syndromes of ARS such as bone-marrow and intestinal syndromes and their combinations, which are characteristic for dose range I-I6 Gy (IOO-I6O rad). Less penetrating, only to the depth of skin, beta irradiation (T.G. Protasova, T.I. Davydovskaya) at the doses at least IO to 20 times higher than average whole-body dose became the cause of the vast radiation injuries of the skin in more than I/2 of the patients. These injuries significantly aggravated the clinical course of sickness and greatly influenced the outcomes. Sometimes on the background of shallow radiation injuries the isolated centers of more deep local radiation injuries (LRI) have arisen as a result of local application or contact with the objects contaminated by radionuclides such as the wet clothes or boots.

No regular correlation was found between the radionuclide content measured during life, post-mortem investigation and the clinical manifestations. As was formulated earlier (I,2), the action of incorporated nuclides has not brought about the evident contribution to the clinical picture of the prodromal phase of ARS for the given irradiation situation.

According to the results of gamma-spectrometric measurements of blood samples (I.A. Gusev, A.A. Moiseev), of urine (R.D. Drutman, V.V. Mordasheva) and of post-mortem samples of organs and tissues (I.A. Gusev, V.I. Popov) the maximal content of radioactive iodine-I3I in the organism was: for one patient (No. 24), iodine-I3I- 5 mCi caesium-I37,-I34 - 2 mCi, for another patient (No. 25), iodine-I3I - I mCi, caesium-I37,-I34 - 2.5 mCi. Contamination by cerium-144 was not higher than 30 μCi (about 95% of cerium activity was deposited in the lungs).

The content of other radionuclides (zirconium-95, niobium-95, ruthenium-I03,-I06, lanthanum-I40, barium-I40, cerium-I4I, etc.) was not higher than maximal permissible intakes separately for each radionuclide.

Although for these two patients the paths of intake (through the damaged skin, by inhalation) are not quite clear, the doses of internal irradiation (conservatively evaluated) are equal to:

for the thyroid gland	30 Gy (No.24) and 6 Gy (No.25)
for whole body	2 Gy (No.24) and I Gy (No.25)
for the lungs	2,5 Gy (No.24) and 2 Gy (No.25)

(the doses are given for a time of death)

For the NPP personnel, who was at the place in the moment of the accident, the mean dose of the lungs irradiation from internal emitters was 0,2 Gy, of thyroid - 2,5 Gy, whole body - about 0,I5 Gy.

In the following table A the data on the internal irradiation of patients from NPP personnel, who died as a result of irradiation due to the accident, are present.

In several reports (I,2,8,II,I2) the clinical characteristics of main syndromes of ARS in the prodromal phase, syndrome combinations with each other and with local radiation injuries were presented.

Table A. Doses of internal irradiation for the persons, who died as a result of Chernobyl NPP accident

Patient No.	Thyroid dose, Gy	Lung dose, Gy	Whole body dose, Gy Internal	External
24	30	2,5	2,0	I,7
25	6	2,0	I,0	4,7
I7	I	0,4	0,2	I0,0
3	0,3	0,3	0,2	I2,0
4	I,2	0,4	0,I	II,0
26	0,5	0,3	0,I	I2,0

Notes: I. The doses are given for the time of death.
2. The data are given only for the patients with the highest values of internal doses.
3. In the last column doses of external gamma exposure are presented.

Here we are demonstrating once again Fig.I (from report (2)), which shows those relationships and the frequencies of lethal outcomes in the different groups of affected persons. As the figure showes at 3-4 degree of ARS nearly in all the patients the severe bone-marrow syndrome (BMS) is combined with skin and mucosa injuries. In 4/5 of the patients with BMS of 4 degree the intestinal syndrome has developed, and in part of them (7 patients) pneumonitis with pronounced breathing insufficiency was observed.

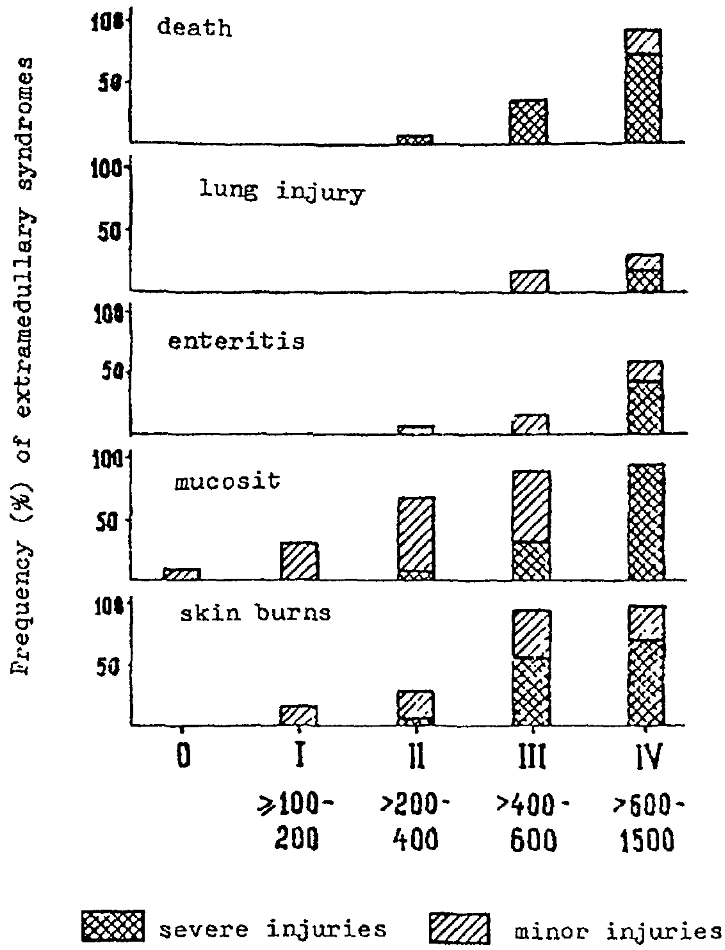


Fig.I. Ratio of different syndromes frequency in various dose range (at bone-marrow syndrome of various degree).

The aggravating contribution of pronounced and/or extensive skin injuries was evident in all the patients. For the people with the area of radiation burns greater than 40% of body surface (2/3 of the persons with lethal outcomes) burns should be considered, basing on the clinical data, as the leading cause of the outcome of sickness. Skin lesions were the sole cause of the death in 5 patients. The role of skin injuries was significant for early as well as delayed times of death.

The way of grouping the patients according to the prognosis development of bone marrow syndrome at different stages of observations made for choosing appropriate volume therapeutic treatment was given in detail in a few publications (5, 6, 11, 12).

We will indicate again only to the high practical significance of such characteristics as the number of lymphocytes at the first 3-7 days after exposure, the number of neutrophiles at 7-8 days, the time period to reach count of neutrophiles < 1000 (at I-5 weeks of observation) and the period of the development of clearly pronounced thrombocytopenia (from 2 weeks till the end of prodromal phase; for ARS I degree - till 4-6 weeks from the moment of exposure, Fig.2).

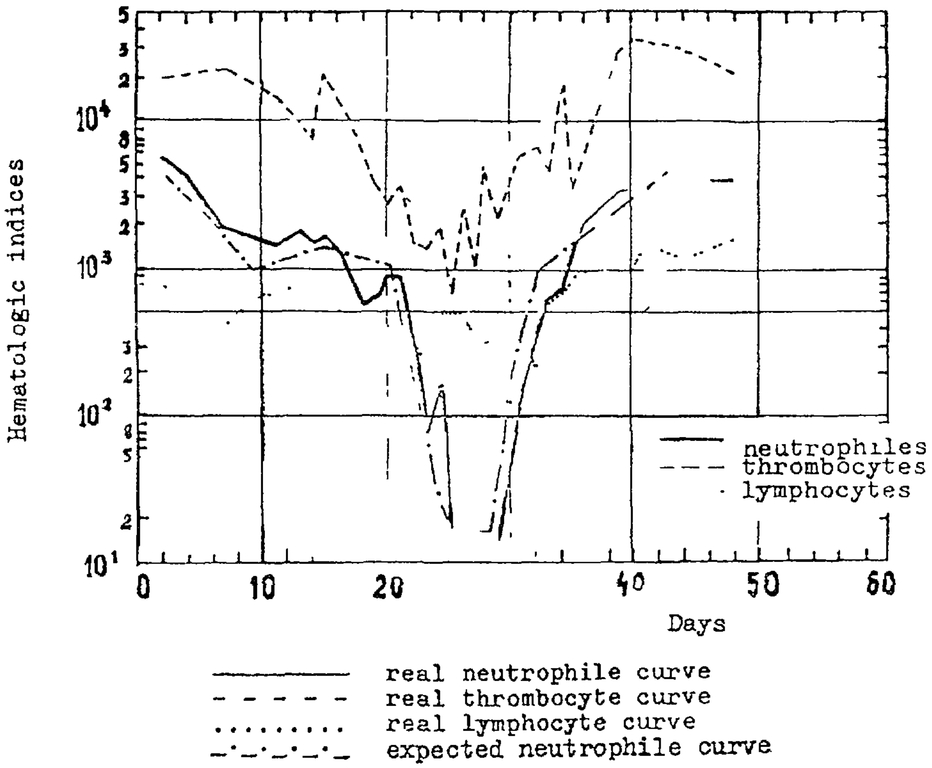


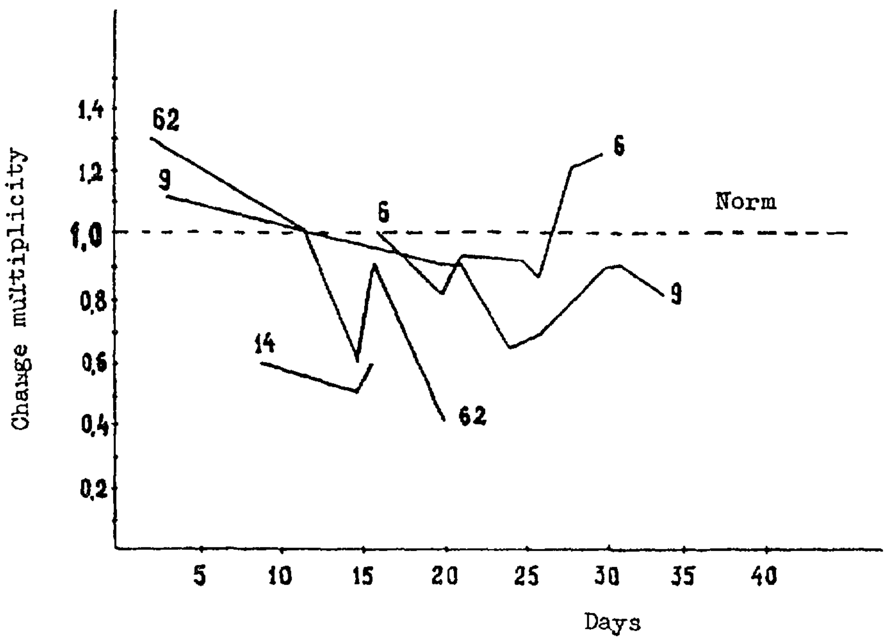
Fig.2. Ratio of expected and real dynamics of periphery blood picture in victims of the Chernobyl NPP accident.

The highly significant data of the cariological analysis of bone-marrow lymphocytes and peripheral blood lymphocytes as well as the results of direct count of dividing cells in biopsy preparations of hemapoietic organs also have been discussed earlier (I,5) and later completed by quantitative information.

As it was earlier mentioned (see Fig.2) the informativeness of the dynamics of quantitative indicators of blood picture was the highest with respect to the subsequent course of ARS.

The other clinical (neurological, ophtalmological) and laboratory tests (immunological, coagulation, metabolic indicators) have shown mainly the correlation with some separate clinical syndromes of ARS and its aggravations (nerve system injuries, toxemia, bleeding).

For biochemical tests (I.P.Turina, M.P.Tarakanova, T.A.Ivanova) the correlation with the severity of sickness was the best for some indicators of protein metabolism and enzymatic activity (I, I2). So the pronounced hypoalbuminemia from IO to 30 days after exposure was observed in patients with severe degree of ARS (especially with intestine injuries) and a big surface of beta-dermatitis (Fig. 3). In the critical phase of sickness the maximal manifestations of infectional, inflammatory and necrotic changes coincided with the period of hyper- alpha 1 and alpha 2 globulinemia.

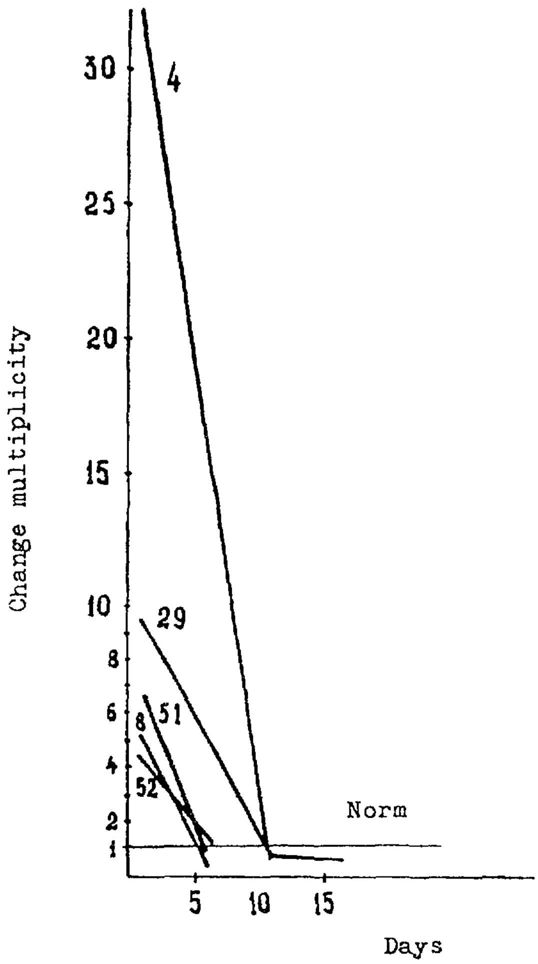


Note: Size of injured skin surface and degree of radiation injury in patients.

NI4 (60% - II-III)
N62 (90% - II-III)
N6 (50% - II-III)
N9 (46% - I-III)

Fig.3. Albumin content in blood serum of patients with the acute radiation syndrome of III-IV degrees.

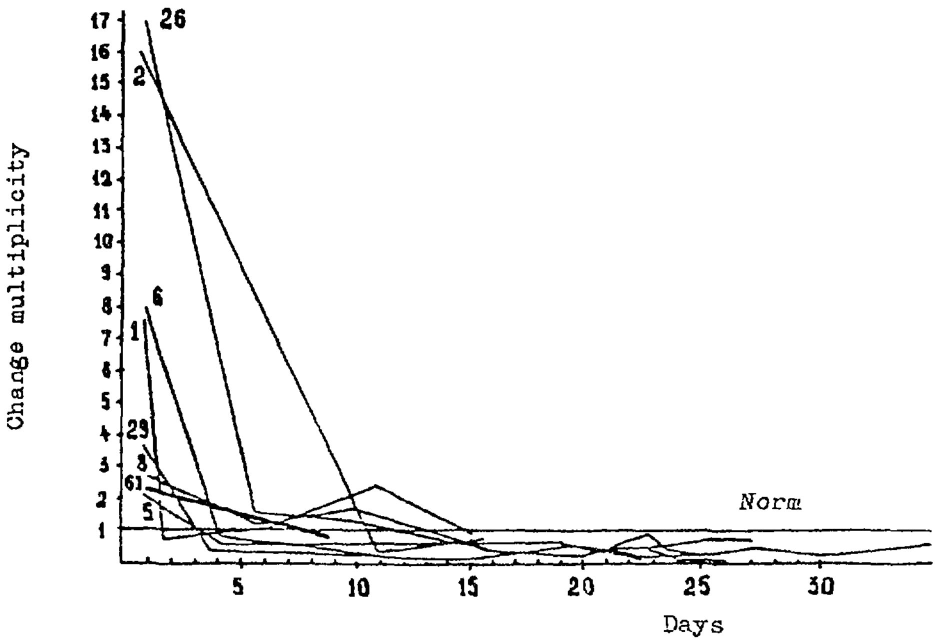
The increase of activity of alpha-amylase at I-5 days in its expression correlated with the severity of general manifestations of ARS and, especially, with subsequent oropharingeal syndrome (Fig. 4).



subject N	degree of BMS (bone-marrow syndrome)	degree of oro-pharingeal syndrome (OFS)
4	IV	IV
29	IV	IV
5I	II	I
8	IV	IV
52	III	II

Fig.4. Activity of blood serum alpha amylase in patients with the acute radiation syndrome of various degree. Degree of bone-marrow injury.

The increase of activity of cretinkynase at 3-IO days have been connected evidently with the size of injured skin surface and severity of beta-dermatits (Fig. 5).

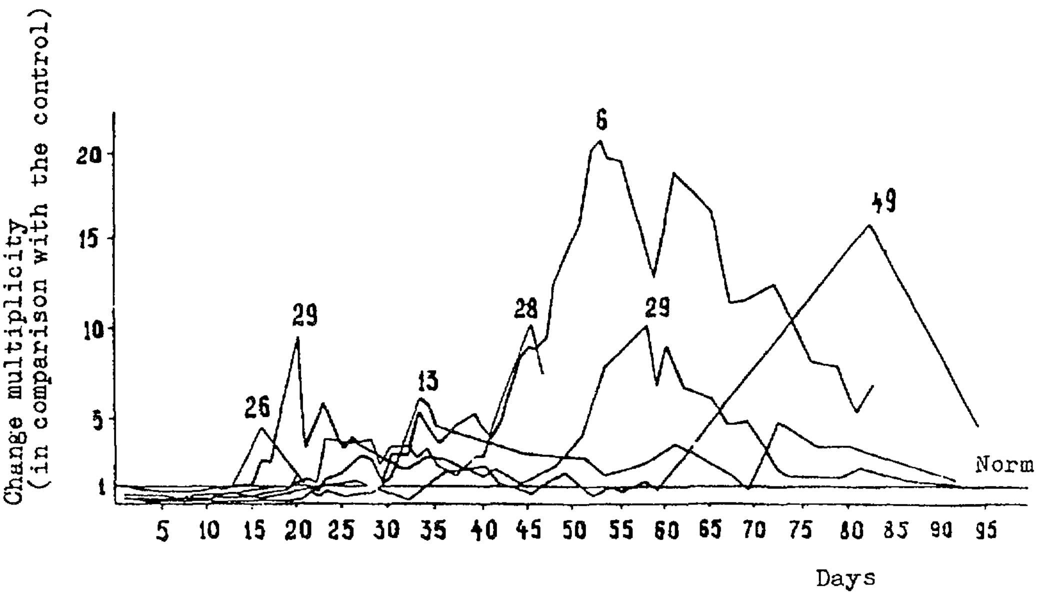


subject N	degree of skin radiation injury	size of injured skin surface	degree of BMS
26	II-III	60%	IV
2	III-II	96%	IV
6	I-III	46%	IV
I	II-III	50%	IV
29	I-III	40%	IV
8	I-II	25%	IV
5	II	6%	III
6I	I-II	I8%	II

Fig.5. Activity of cretinkynase in patients with various degree of bone-marrow syndrome (BMS), size of injured skin surface and degree of radiation injury.

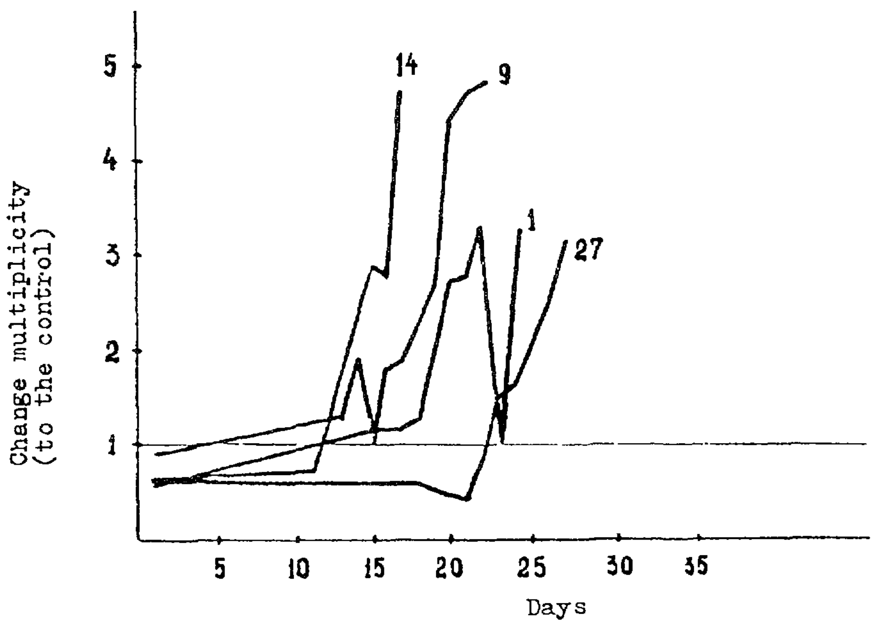
In critical phase of ARS and in case of aggravations hyperfermentmia was observed as the small second wave of the increase in activity of creatine-phosphokynase and as the evident increase of the blood content of alaninaminotranferase, asparaginotransferase, gamma-glutamine-transpeptidase (Fig. 6).

In terminal phase for extremly sick patients the increase in blood (and urine) of the creatinine and urea content was noted (Fig.7). However, in general, due to corrective therapy the changes of all these indicators rarely reached extreme values. In all patients survived these indicators have shown clearly positive dynamics and in those patients who died the fatal character of indicator changes had appeared only in last days of their life.



subject N	degree of BMS	subject N	degree of BMS
6	IV	28	IV
I3	III	29	IV
26	IV	49	II

Fig.6. Activity of alaminotranferase (ALT) in various periods of the examination.



subject N	degree of BMS	subject N	degree of BMS
I	IV	I4	IV
9	IV	27	III

Fig.7. Typical dynamics of urea content in blood serum.

Bone marrow transplantation aggravated by secondary illness (3, 8) found its reflection in the dynamics of biochemical indicators which have been used in particular for indentification of this secondary illness.

The analysis of neuroimmunological changes (studies of the titres of circulating antibodies to the brain antigen and myelin protein, the reaction of inhibition of migration and specific agglomeration of leucocytes, quantitative relationship of T and B forms in accelarated reaction of rosette farmation) in comparison with the clinical neurological picture (I.N. Shakirova, L.I. Muravieva) was also made. It was shown that after general irradiation the threshold value of the dose after which the minimal signs of microdestruction of brain tissue could be found by immunological tests in the prodromal phase of ARS are about 2 Gy. The intensity of neuroimmunological shifts was forced by toxic influences of local radiation injuries. In the course of the observation the computer program for the use of the data of coded sickness history of neurological syndrome was created and tested (I.N.Shakirova and S.M.Shendyapin).

The state of hemostasis in accident victims was determined by direct action of ionizing radiation (the injury of thrombocytopoiesis, structural changes of blood vessel walls) as well as indirect one (L.S. Pochukaeva).

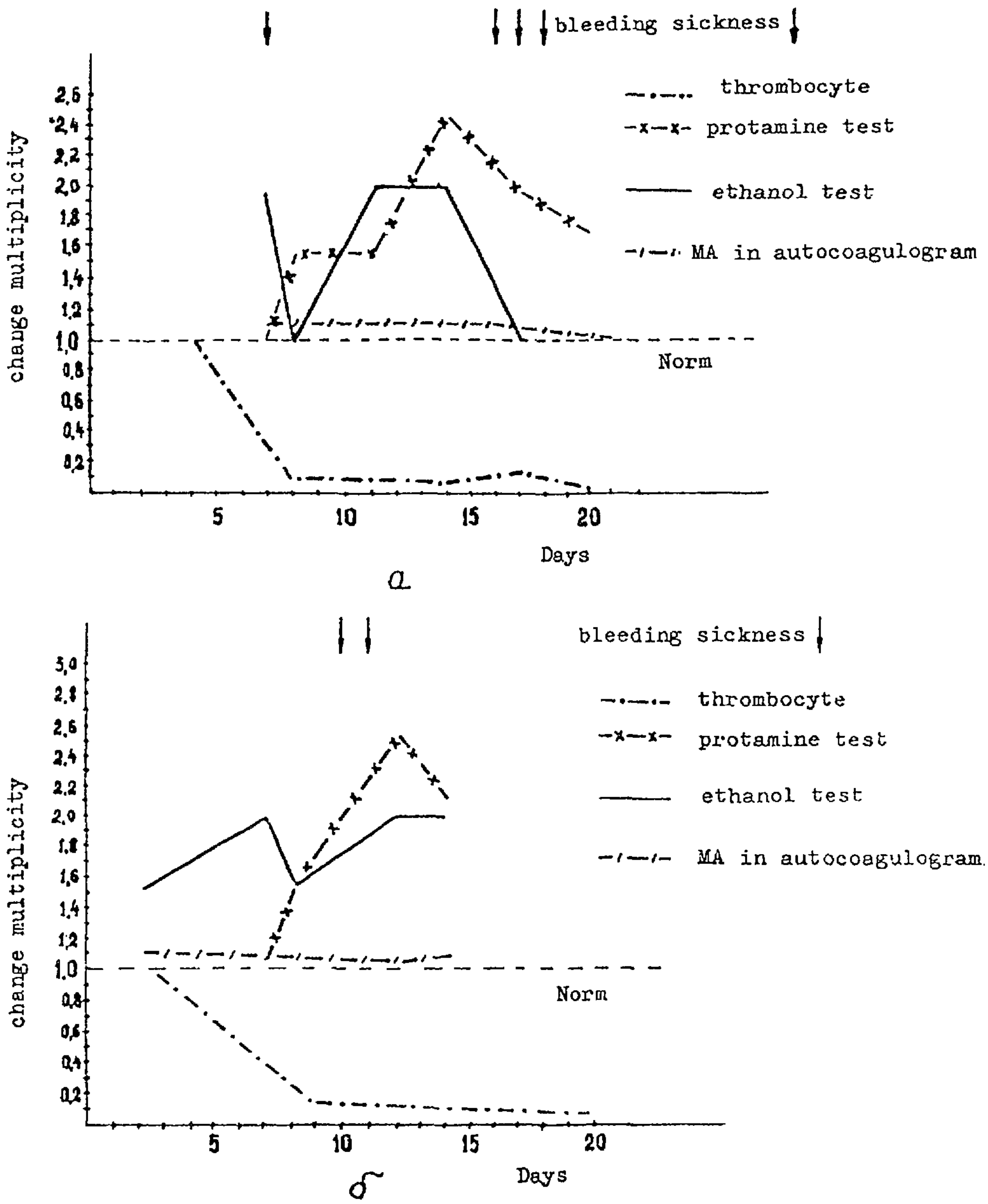
The activation in coagulation step at all times of prodramal phase of sickness (the increase in maximal activity of thrombin thromboplastin in autocoagulation test, the permanent presence in the patients blood of soluble fibrin monomeric complexes) was found. These changes could help intravascular coagulation of blood. The increase of fibrinolysis in latent phase of ARS of intermediate degree made possible the dissolution of fibrin formed and the liquid state of the blood in the vessels. In especially heavy cases of injury this mechanism of feedback was broken and the blockade of fibrinolysis lead to precipitation of fibrin and formation of blood stasis in microcirculatory vessels. It could lead to the disruption of organ functioning and to the secondary changes of the vessels walls.

On the background of the activation of the system of hemostasis and of the presence of microclots and microthrombs there was enhanced inclination for hemorrhages even in the case of minor vessels injuries. Thus the reaction was paradoxical, while hemostasis activation was not leading to hemostatic effect (Fig.8).

As the result of permanent observation of patients for one year and a half no necessity to reconsider the degree of severity of ARS 2-4 has arisen. The course of sickness in prodromal phase as well as in recovery phase corresponded to our previous ideas (5,6) about peculiarities of acute radiation sickness resulting from total relatively uniform exposure in the indicated dose ranges.

It seems appropriate to come back and give special attention to the criteria of diagnostics of slight degree of ARS and to the few observations in the subclinical range of doses to find out more distinctly at what dose levels and in what time the individually significant clinical signs of the reaction of organism to exposure could reveal itself (5,6,IO).

After careful analysis of most full blood changes, observations made in specialized in-patient facility it became clear, that regular changes of leucocyte and thrombocyte counts in patients appear only at 5-6 week after exposure. There may be a shift of these symptoms for several days (about I week) with earlier appearance of the change in thrombocyte count. The primary reaction could be expressed in those cases in different degree, but appears regularly in the later terms (up to several hours after irradiation) and only in such signs as nausea and vomiting.



(a – subject N26, b – subject N25)

Note: All the indices are given on multiplicity of deviation from the norm, the arrows mark the manifestations of bleeding sickness. The therapy by plasma and heparin was carried out.

Fig.8. Typical ratios of hemostasis indices in patients with acute radiation sickness and DVS syndrome.

The external exposure doses in this group of patients according to the data of cariological analysis (the frequency of dicentrics) were in the range of 0.8-2 Sv (80-200 rem).

At the retrospective consideration of the cariological data for the group of persons, who have been considered in the early terms of observation as possible patients with ARS of I degree due to different and not only to above mentioned symptoms, there were found the following regularities (A.V. Barabanova, A.V. Sevankaev, M.V. Konchalovskij).

From 2I persons, whose irradiation doses have been estimated between 0 and 0.6 Gy according to cariological data, nobody showed the characteristic symptoms of ARS.

In 20 persons with doses estimated according to cariological data between 0.7-2.I Gy it was possible to speak about the acceptability of diagnosis of ARS I degree, and the dynamics of neutrophiles count indicated the mean doses in bone marrow about I-2 Gy.

Thus, the dose of whole-body irradiation 0.7 Gy could be tentatively considered as minimal dose leading to weak but regular individually significant changes in blood picture, which are characteristic for ARS I degree.

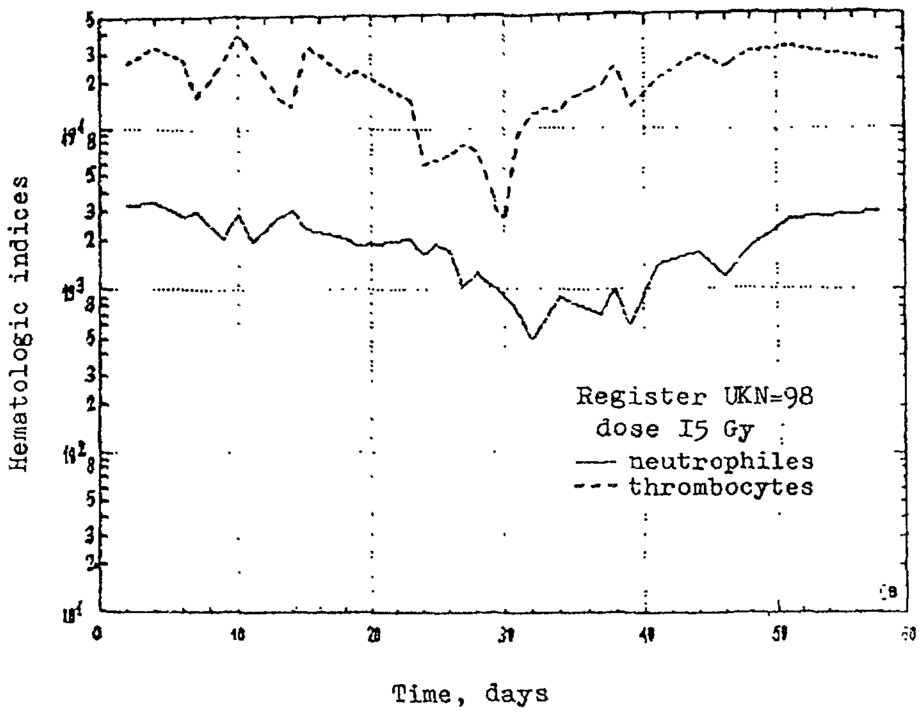
Good coincidence of the cariological data and of whole dynamics of neutrophil count permits one to come again retrospectively to the validity of diagnostics of slight form of ARS. The diagnostics is possible for irradiated persons even in the case of absence of information on dose levels, as well as in the case if some information about doses in border region (0.6-I.2 Gy) is present.

We are using those rules systematically adding to them the available methods of dose reconstruction.

The following graphs (Fig. 9) illustrate the characteristic dynamics of neutrophil counts in the case of ARS I degree.

The first variant of diagnostic computer program unifying the approaches to the diagnostics of ARS I degree have been developed.

The assessment of effectiveness of treatment was one of the aspects which have been additionally analysed. The main principles and direct results of treatment of ARS of different degree of severity were discussed in several reports (II, I2).



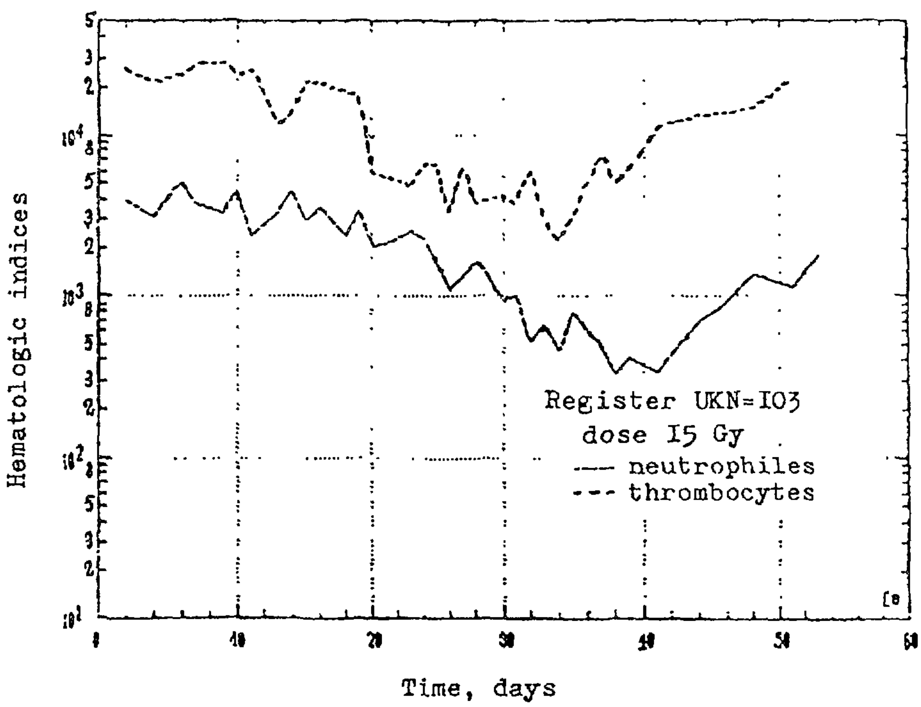


Fig.9. Typical curves of dynamics of leukocyte (neutrophiles) and thrombocyte number in 2 patients with the acute radiation syndrome of minor degree.

The analysis of the causes of lethal outcomes as well as the data on the dynamics of clinical and laboratory indicators of living patients studied to this moment serve as addititonal criteria of the effectiveness of treatment.

Let us consider in regular order the short preliminary results of those two aspects of observations. As it was said before due to ARS 3-4 degree, 27 patients have died and one woman due to ARS 2 degree. The times of death differed from II to 96 days including two patients with combined thermoradiation injuries.

Further, the data on main elements of pathologo-anatomical pictures of the patients, who had died due to ARS and its combinations with radiation and thermal injuries of skin in time from II to 96 days after accident, are given. Specially stressed are the cases with unusual causes of death for a given time of observation.

For all the patients the pronounced severity of the course of sickness was noted due to combination of 2-3 clinical syndromes and complex spectrum of toxic and infectional aggravations and circulatory deficiencies. The skin lesions covering the significant part of body surface came forward as one of the leading causes of death in the structure of tanatogenesis for all terms from the moment of irradiation. For death occured earlier than 24th day, the skin lesions were accompanied not only with heavy disruption of hemopoiesis but also with early pronounced intestinal syndrome.

As life times were increasing, the skin injuries have been more frequently connected with one from two syndromes of ARS (bone marrow) or acquired the independent significance in the outcome of the sickness.

The combinations of syndrome, their aggravations and the direct causes of death are much more varied in times from 24 to 48 days after exposure. It gives the impression, that by excluding some of these aggravating circumstances for these terms it could be possible even to change the outcome of the sickness. In several persons for these times on the background of heavy injury of hemopoiesis there were slight but distinct signs of centers of regeneration of bone marrow and of regenerating parts of intestinal mucosa.

For the outcomes in the end of the second month the extremely high severity of infectional (including viral) aggravations was typical as well as dystrophic changes in parenchymatous organs.

For many patients and for different terms the various circulatory disfunctions in capillaries with the most frequent localization in lungs, under mucosa and in the brain were characteristic. Heavy, fatal haemorrhages were rare.

In general the assessment of the effectiveness of the whole complex of measures for treatment of ARS taking into account the severity and combinations of clinical syndromes could be.given as quite satisfactory (I, 2).The analysis of the effect of bone marrow transplantation for the limited group of patients is given in special report by A.A.Baranov at this conference.

It is dificult to give the assessement of the other separate components of the treatment. However, taking into acount the data of postmortem morphological studies, it is possible to speak about definite effectiveness of the system of prophylaxis and therapy of infectional and especially bacterial aggravations. It was achieved by isolation of the patients and by organization of special aseptic regimen for the patients in the period of agranulocytosis, by therapeutic and prophylactic use of antimicrobial and antifungal drugs and in some cases by local application or injection of antiviral drug (aciclovir). Only in 7 from 27 persons who died to ARS of 3-4 degrees the diagnosis of sepsis (in 4 cases mixed fungal and bacterial, in 3 cases bacterial) was confirmed after pathologo-anatomical and postmortem microbiological studies. In others, microbial contamination of tissues was not pronounced, and only insignificant number of colonies was noted for necrotic surfaces of skin and mucosa.

The other important component of treatment scheme was the replacement therapy by blood components. The evident direct effectiveness of allogenic and autological cryoconservated thrombocytes should be specially stressed. For one patient with 2-3 degree of ARS 3-8 transfusions of platelets (300,000,000,000 in one portion) have been used in average. Such regimen ensured the absence of life-threatening bleeding for the overwhelming majority of patients with bone-marrow from of ARS not aggravated by other syndromes. This effect was observed even in the case of long-term (I4-20 days) and profound (< 5000 cells/microliter) thrombocytopenia.

As the direct cause of death the haemorrhagic syndrome was observed for one patient. Haemorrhage was provocated by traumatic manipulation when catheter was introduced into the subclaviculer vein.

For the correction of metabolic disturbances and also in the case of impossibility of direct tract mucosa the undcubted direct effect gave total parenteral nutrition. All necessary means for symptomatic therapy were also used (in cases of the signs of brain oedema, toxic nephro- and hepatopathia, discirculatory and hypoxic encephalopathia). However, the combination of two or three syndromes as the rule was fatal.

Due to these facts it is hardly possible to estimate LD-50 as we already mentioned at the experts meeting in August I986. Some kind of general quatitative characteristic of the therapy effectiveness could be the information about frequency of lethal outcomes for groups of patients with different degrees of severity of ARS.

As it was mentioned above we lost one of 53 patients with 2 degree of ARS, whose irradiation dose was 4.I Gy, on the background of practical recovery from ARS.

From 2I patients with 3 degree of ARS (dose range between 4.0 and 6.0 Gy) survived I4.

All patients besides one with 4 degree of ARS have died, but, as the analysis of pathologoanatomical data shown, the death came as the result of combination of several clinical syndromes and, in first place, of the combination of intestinal and bone-marrow syndromes with total or subtotal injuries of skin.

The times of death after combined thermoradiation injuries were I6 and 23 days in the presence of the slight degree of intestine injury for one patient and of bone marrow for the other, what shows the leading role in tanatogenesis of skin injury (patients No. 25 and No. 24).

The breathing problems were of complex and nonuniform nature for persons, who died at different times. According to the results of pathologo-anatomical studies they were significantly pronounced for I3 persons and were especially significant for 7 of them. There were signs of expressed circulatory disturbances, the injuries of alveolar-capillary level and interstitial oedema for all times of observation and typical fibrillar-haemorrhagic manifestations in persons, who died at later terms.

In the course of a year and a half the dynamic observations of all those persons who had acute radiation sickness (ARS) were continued to assess the completeness of recovery processes. The process of haemopoiesis recovery came very actively: in 84% of patients after I-I.5 year the normal blood picture have been restored.

The distinct dependence of the completeness of recovery from severity of sickness manifestations in prodromal phase (from dose of general irradiation) was found (V.N.Pokrovskaya, N.M.Nadezhina). Moderate, not very stable leucopenia and more rarely thrombocytopenia stayed to the moment of latest observation in 9, I5 and 30% of persons who had ARS respectively I, 2 and 3 degrees. At the same time in I/2 of persons with incomplete recovery even at the first entrance observation the moderate decrease in the number of leucocytes (granulocytes) and/or thrombocytes was noted what indicates insufficient hemopoiesis.

At later terms the moderate unstable cytopenia evidently increased and was due to the illness of digestive tact previous to ARS (hapatitis, gastritis, ulcer).

All patients with ARS 3 degree suffered from local radiation injuries. For all of them having cytopenia the prolonged treatment including plastic surgery was necessary.

The studies of capacity for physical work and of energy expenses (V.V.Charitonov, O.P.Efremovtseva) have shown favourable dynamics of these indicators gradually increasing in course of recovery from ARS. The time and completeness of recovery depended in a certain degree on the severity of the sickness (or irradiation dose).

The studies of capacity for work and necessary energy expenses for it allowed to note following regularities.

The group of persons without clinical signs of ARS in all times of observation (up to one year) preserve the ability to fullfill work at significant levels of energy expenses - 4.9 kcal/min are characteristic for patients with ARS I degree.

The patients with ARS of 2 and 3 degrees of severity differ from the considered above groups of patients even at the latent phase of sickness, and their ability for work is limited by energy expenses not higher than 3.0-3.8 kcal/min.

For the patients with ARS I and 2 degree the levels of physical ability are restored already at 8, 9 week and stay at high values till the end of year after irradiation.

For the patients with ARS 3 degree the indicators of capacity for work at the phase of early recovery are worse than initial (3.5-3.8 kcal/min respectively) and even to the end of the year does not reach the normal levels.

The reactions to the physical stress significantly differed individually because of different age, physical conditions and previous illness of the patients.

Very interesting are the results of complex clinico-psychological studies of neural and psychic activities (F.S.Torubarov, P.V.Chesalin, O.V.Chinkina). Complex stress and radiation situation brought about to the development of objective signs of moderate asthenization in early recovery period (4-6 month after accident) only in part of the patients. Asthenic manifestations correlated in its frequency and expressiveness with the severity of sickness (3/4, I/2 and I/3 in persons with ARS 3, 2 and I degree respectively). However, even this time together with still unfinished recovery processes in somatic sphere certain significance for the development of asthenia had premorbid peculiarities of personality, attitude of patient to the risk of irradiation and sickness, the degree of information, profession and the construction of oriented basis for future working and common life. In later terms (9-I8 month) the leading role of somatic basis of asthenia (ARS severity in the phase of formation) had passed, especially because the definite recovery in the function of main organs and systems was observed. Asthenia depended on the socioprofessional factors indicated above, adequacy of the new working place and previous to the sickness personality peculiarities of the victim.

Our experience shows, that in choozing the indications or contra-indications for some kind of work the objective many-sided study of physical and psychic efficiency, structure of self-estimation, psychic condition of personality, reactions and peculiarities of personality adequate to the considered work have great practical sifnificance. Rational choice of working place and favourable socially-personal rehabilitation help to reach the high degree of recovery of working activity of full value even in patients who had suffered ARS 2 and 3 degree.

The whole complex of all clinical and paraclinical methods of study give the possibility for the overwhelming majority of ARS patients (5/6) to limit in future only the contact with radiation sources. Only the small number of them, as the rule suffering from intercurrent illnesses, were limited in relation of working regimen (exclusion of night shifts, usage of protective cloth, gloves, etc.) (N.M.Nadezhina, A.V.Barabanova).

Acknowledgement of temporal invalidity for next I-2 years in patient was mainly motivated by reidual manifestations of local radiation injuries, high degree (3) of ARS severity or by combination of ARS with other illness.

Dynamic observation of patients in the second year after the accident shows in 3/4 of them undoubted improvement of capacity for work excluding three patients (I with local radiation injury, 2 - non-rational choice of working place). It gives the possibility of gradual broadening of regimen of their working and social activity.

It should be noted, that correct choice of work adequate to general conditions of the person after ARS, personal interest in this work gives the evident favourable emotionally-psychological influence and stimulates functional recovery.

The completeness of social -personal rehabilitation after ARS was clearly demonstrated to the whole world when on the TV screens of Italy, Great Britain and USA appeared our patient L.P.Telatnikov, who now actively works at the Center of fireman training.

Such examples could be many times multiplied including the cases when high professional capacity for work was retained (without or with limited contact with radiation). These patients are engineers and operators of NPP who suffered ARS of I-2 degrees. Several persons are working now at Chernobyl NPP and their radiation doses in I987 were not higher than 0.6 rem.

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TRANSPLANTATION OF BONE MARROW IN VICTIMS OF THE CHERNOBYL ACCIDENT

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Abstract

Bone marrow transplants were carried out in 13 patients suffering from acute irradiation sickness after the Chernobyl accident. Only blood relations of the patients were used as donors. The number of bone marrow cells transplanted must be at least 2 x 10^8 per kilogram of recipient weight.

The experience of the present bone marrow transplants has shown defects in clinical methods of early diagnosis (during the first 7-10 days after exposure) of acute radiation injuries to the skin, intestine and lungs which are incompatible with survival.

Another problem with bone marrow transplants for patients suffering from acute radiation sickness is to determine to what extent the depression of marrow activity is irreversible. Spontaneous regeneration of myelopoiesis was observed 22-30 days after exposure in patients who had received doses of 7-9 Gy. A lapse of this order before the onset regeneration is therefore, in principle, compatible with survival under the conditions of modern support therapy. Thus, the belief that prolonged acute radiation pancytopenia which is incompatible with survival starts already at doses of 5-6 Gy is evidently incorrect, at least for the relatively low exposure dose rates experienced by this group of victims.

The results of bone marrow transplants in victims of the Chernobyl accident suggest that, in future, the following rules should be observed in transplanting human bone marrow to victims of acute radiation sickness:
(1) Only HLA-identical transplants should be carried out; and
(2) HLA-identical bone marow transplants should be carried out only in patients who have received whole body doses of gamma radiation of 9.0 Gy or more.

The experience gained in myelotransplantation following accidental exposure of healthy humans (acute radiation disease of humans), and available for analysis is scarce, as it comes to transplantations of bone marrow without matching by HLA in patients injured during reactor break-down in Zince (Yugoslavia), and a single case of syngeneic transplantation in Pittsburgh (USA) in 1967. For this reason, bone marrow transplantation (BMT) performed in patients injured during the accident at the CNPP, were guided by the following principles, formulated on the basis of experience of treating acute radiation disease (ARD) in humans and applying BMT after exposure to superlethal doses in hemoblastoses.

I. Transplantation of allogenic bone marrow in ARD patients is indicated in cases of severe or extremely severe (irreversible) damage of myelopoiesis, occurring when doses of total short-term uniform external gamma-irradiation reach 5.0-6.0 Gy and more.

2. Transplantation of HLA-identical, HLA+haplo+I-identical and HLA-haploidentical bone marrow is allowable, though in the last case it may be performed only after removal of T-lymphocytes from the graft.

3. At any degree of histocompatibility between donor and recipient the prophylaxis of acute secondary disease ("graft-versus-host" disease) is mandatory, as well as, probably, prophylaxis of transplant rejection (particularly in cases of HLA-nonidentical grafts). This prophylaxis is carried out by using immunodepressants (methotrexate, cyclosporine A, antilymphocyte globulin) after transplantation.

4. The number of transplanted bone marrow cells should not be less than 2 x $I0^8$ per I kg b.w. of recipient.

5. Absence of negative effect in similar allomyelotransplantations in ARD patients with reversible degree of myelosuppression, or even their beneficial effect, due to reduced terms of pancytopenia associated with temporal engraftment of the transplant or its low-stimulating effect.

Proceeding from the above principles we have carried out BMT in I3 ARD patients injured by radiation during the accident at CNPP.

During the accident the patients had no emergency dosimeters. The rate of external total gamma-irradiation of bone marrow was estimated exclusively on the basis of previously developed methods, that is by the number of lymphocytes and neutrophilic granulocytes in peripheral blood and by amount of aberrations in the culture of peripheral blood leucocytes.

Some patients, despite the anticipated severe and extremely severe myelosuppression suggested by dosimetric data, did not undergo BMT because of the following circumstances: I) clinical conclusion on incompatible with life lesions of skin and (or) intestine; 2) lack of a suitable donor; 3) conclusion made on the 10th to 13th day of the follow-up that recovery of the patient's own hemopoiesis is feasible.

Hematologic indices of these patients served as control values in relation to patients undergoing BMT.

The donors were selected only from the patient's close relatives (brothers and sisters, parents). Typing of donors and patients for HLA was performed only with respect to antigens of A, B, C loci employing here standard antisera.

The bone marrow was taken from donors according to the technique described by E. Thomas and R. Storb. If incompatibility between the blood group of donor and recipient was significant, the erythrocytes were removed by myelokariocytophoresis with bags for blood transfusion after pretreatment with polyglucan. T-lymphocytes were removed from haploidentical transplants by Dr. Y.Reisner , one of the authors of the given method, in conformity with the technique described earlier.

To prevent acute secondary disease all patients received cyclosporine A (CSA), and some of them were given additionally methotrexate (MT) or antilymphocyte globulin (ALG). Usually CSA (Sandimmun , Switzerland) was injected intravenously 24 hours before or 0-3 days after transplantation: the first dose of I2.5 mg/kg was administered in the form of 8 hr infusion, later followed by 3-6 mg/kg a day (equal doses every I2 hr in the form of 3 hr infusions). Cyclosporine dose was variable depending on its level in the whole blood, which was maintained within the range 400 and 600.

Methotrexate was used according to the scheme described in the protocol from Seattle, that is I5 mg/m^2 24 hours after BMT followed by IO mg/m^2 3, 6, and II days later.

ALG (Lymphoser, "Serum-&-Impfinstitut Bern" Switzerland) was administered on alternate days only to patients who underwent haploidentical BMT in doses 20 mg/kg b.w. as a single 6-8 hr infusion.

All the blood preparations were irradiated on a gamma-therapeutic apparatus (Co^{60}) (dose I5.0 Gy).

For prophylaxis and therapy of thrombocytopenia hemorrhage, there were made infusions of platelet mass, derived mostly by a method of repeated 4-fold thrombocytophoresis in healthy donors. Leucocytic mass was not transfused for prevention and treatment of infections.

The principal clinical findings, data on doses of total gamma-irradiation, assessed by various techniques, results of BMT, length of survival and causes of fatal outcome in ARD patients who underwent bone marrow transplantation, are presented in the table.

By level of total gamma-irradiation dose all the patients with BMT may be assigned to three groups: I group with radiation dose 9.0 Gy, in group II it ranges 6.6-8.7 Gy, and in group III 4.4-6.4 Gy.

Dynamic changes in number of neutrophilic granulocytes, platelets and lymphocytes in 6 patients with BMT and in 5 patients without BMT, whose total radiation doses ranged from 9.2 to 13.4 Gy, and from 11.2 to 13.8 Gy, respectively was within 10 days after the exposure approximately the same.

The neutrophil count was noted to be restored in patients from the group with I3 MT. It seems reasonable to assume, that in one case (UCN 9, dose 9,6 Gy) the restored count was due to survival of HLA-identical graft. The patient died on the 23d day, and the main causes of his death were II-III degree burns of skin, injuring 50 % of body surface.

In the second case (UCN I6, dose IO.2 Gy, HLA-haploidentical BMT), the patient's own myelopoiesis failed to recover completely, that is confirmed by karyologic studies (see the Table). The patient died on the 9I (+79) day from cytomegalovirus interstitial pneumonia (proved by histologic examination after his death). Histologic studies of autopsy material also revealed alterations in the skin, liver and intestine, thereby lending support to the diagnosis of acute secondary disease.

All the patients both with BMT and without it, who were assigned to the group with a dose of 9.0 Gy (with exception of one patient, UCN I6) died from severe diffuse radiation burns combined with other acute radiation syndromes (intestinal, otopharyngeal, acute radiation pulmonitis) in the period from I4th to 23d day.

Changes in peripheral blood in 3 patients with BMT and in 4 patients without BMT, who received, respectively, total radiation doses ranging 6.6 to 8.7 Gy, and 6.8 to 8.5 Gy were the following:

3 patients with BMT hematopoiesis started to recover. Regrettably, two of them died on the 25th (+I9) day and 24th (+II) day from severe radiation burns (UCN I, dose 6.6 Gy) and acute radiation pulmonitis, and, probably, ARD (disclosed at autopsy) (UCN 27, dose 8.3). One patient (UCN 29, dose 8.7 Gy) has survived and his hematopoiesis has been seen to recover completely. In this case, acute secondary disease has been suspected because of fever with unclear genesis observable within I3th-57th day, which could be relieved solely by high doses of methylprednisolone (see Table I).

In two patients of 4 without BMT (UCN 22 and 3I, doses 7.I and 6.8 Gy) the number of blood neutrophilic granulocytes started to be restored on the 24th and 22d days. One patient from this group (UCN 22) has survived, his hematopoiesis has completely re-

Table I.

Clinical data, radiation dose, bone marrow transplantation and disease outcome in 13 ARD patients

NN	Unique clinical number	Age	Dose[2] of total gamma-radiation Gy, assessed by: L	D	N	Index of irreversible myelosupression[3] (IIM)	Radiation burns of skin: degree	area % of body surface	Onset of diarrhea (day)	BM transplantation: Day after exposure	Donor[4], sex, relatives, age	HLA[5] compatibility	ABO rhesus donor/recipient	Dose of BM cells x10 kg	Immunosupression[6] induced by BMT, days after BMT: MT	CSA	ALG	BM engrafment: day 500 neutrophilic granulocytes after BMT	% mitosis XX in BM\day after BMT	ASD[7]: Degree according to clinical data	MP[8] treatment, days after BMT	Length of survival after exposure[9] days	Cause of fatal outcome[10]
1	1	28	10,6	6,6	6,5	+15	I-III	50	-	6	F,56		comp.	1,56	1,3,6	1-13	-	18	-	0	-	25	RB
2	2	32	9,3	9,2	8,1	+ 9	I-III	96	8	4	B,26		comp.	2,25	1,4,6	3-11	-	-	-	0	-	15	ARP,RB
3	3	25	12,1	-	9,2	+30	I-III	60	6	6	S,27		comp.	2,05	1,3,6	1-9	-	-	0/11	0	-	17	RB,ARIS
4	4	25	7,1	11,9	8,7	+19	III-IV	100	9	7	M,50		comp.	2,37	1,3	0-9	-	-	0/11	0	-	18	RB
5	9	46	5,8	9,6	9,5	+30	II-III	50	8	12	B,49		A/0	2,24	-	1-5	-	10	-	0	-	23	RB,ARIS, ARP
6	17	27	13,4	-	9,5	+34	II-III	50	6	16	B,18		0/A	0,67*	-	-	-	-	-	-	-	-	RB,ARIS ARP
7	27	33	5,6	8,3	7,7	-7	III	20	-	13	B,30		comp.	1,96	-	1-9	-	11	-	II	9-11	24	ARP,ASD
8	16	23	10,5	10,2	9,3	+27	II	25	-	12	M,53		3/C	0,92*	-	1-14	5-13	25	26/9,0/14, 24/34,11/42	II	21-29 39-799	91	CMV ASD
9	29	25	4.7	9,7	7.9	+ 4	I-II III	30 10	-	14	S,18		comp.	0,23	-	2-13	5-13	18	50/7,0/12, 15/32,0/40, 0/46,0/54	I-II	13-23	553	-
10	26	46	4,9	6,4	5,5	- 1	I-II	40	-	11	S,59		comp.	0,92	-	1-33	-	16	50/13,90/17 50/-24,100/27 60/37	III	11-33	48	ASD,inf.
11	6	26	5,2	7,6	5,2	- 9	I-II III	40	-	9	B,26		B/0	3,24	-	1-25	-	13	-	II	17-76	86	ASD,inf.

NN	Unique clinical number	Age	Dose of total gamma-radiation Gy, assessed by: L	D	N	Index of irreversible myelosupression (IIM)	Radiation burns of skin: degree	area % of body surface	Onset of diarrhea: day	BM transplantation: Day after exposure	Donor, relative, age	HLA compatibility	ABO: rhesus donor/recipient	Dose of BM cells x10 l/kg	Immunosupression induced by BMT, days after BMT: MT	CSA	ALG	BM engraftment: day 500 neutrophilic granulocytes after BMT	% mitosis XX in BM\day after BMT	ASD: Degree according to clinical data	MP treatment, days after BMT	Length of survival after exposure, days	Cause of fatal outcome
26		46	7,0	4,4	5,1	- 6	II	6	-	7	S,49		0/A	1,77	-	0-18	-	25	100/10,50/16 0/19,10/26	II	-	34	ARF,GHT
13	11	35	6,0	5,6	4,4	-5	I-II	18	-	13	S,31		comp.	0,02**	-	1-13	5-13	19	0/10,14/14 10/36,0/48, 0/72	I-II	43-74	553	-

NOTES: 1). all patients (recipients) are males; 2). radiation dose: L - by lymphocyte count in peripheral blood, D - by number of dicentrics, N - by curves of neutrophilic granulocytes (in detail see "Materials and methods"); 3). see table 1; 4). donor: F - father, M - mother, B - brother, S - sister; 5). HLA-compatibility: - HLA-identical, -HLA-haploidentical, -haplo+1-identical; 6).- immunodepression: MT - methotrexate, CSA - cyclosporine A, ALG - antilymphocyte globulin, doses of drugs - see " Materials and methods"; 7). ASD - acute secondary disease - graft-versus-host disease; 8). MP - methylprednisolone, i.v. 5 20 mg/kg b.w./day; 9). on 01.11.87; 10). causes of fatal outcome: RB - radiation burns, ARIS - acute radiation intestinal syndrome, 10). causes of fatal outcome: RB - radiation burns, ARIS - acute radiation intestinal syndrome, ARP - acute radiation pulmonitis, CMV - cytomegalovirus pneumonia, GHD - "graph-versus-host" disease-reaction of of transplant rejection, ARF - acute renal failure.

* dose of cells after T-depletion of HLA-haploidentical BM.

** low dose of cells - failure at final stage of T-depletion BM.

covered, whereas the rest of patients died within I6-32 days following exposure because of incompatible with life skin lesions, and, to a lesser degree, intestinal damages.

From the 20th and 2Ist day the curves of neutrophilic granulocytes in 2 patients with BMT (UCN 6 and 28) testified to intensive phase of recovery, which, in principle, differed from the recovery phase in patients without BMT and 2 BMT-treated patients. This difference may be attributed to the transplant function: it is in these two patients the stable engraftment of HLA-identical donor bone marrow has been proved by high percentage of female (donor) metaphases in bone marrow at the stage of recovery (UCN 28; see the table), and by augmented amount of donor erythrocytes (up to 65 %) of group B by the 65th day after transplantation in the second case, (UCN 6).

In two other patients (UCN 5 and II) who were transplanted HLA-nonidentical bone marrow the stage of neutrophilic granulocytes recovery occurred at the same time, as in patients without BMT. In both cases the chromosomal markers demonstrated that myelopoiesis recovery was ensured by cells of recipient (see the Table).

In the BMT-treated group 3 patients died (UCN 5, 6 and 28, radiation doses were, respectively, 4.4, 5.2 and 6.4 Gy) from ARD (UCN 6 and 28, both HLA-identical BMT), and from"graft-versus-host" disease (UCN 5, HLA-"haplo+I" BMT) aggravated by fatal viral infections. No fatal outcomes were reported for the control group. Not in a single case the radiation burns of skin or injuriesof other organs were the main cause of death. Radiation burns in patients from the control group were approximately of the same degree and size.

The experience gained in these myelotransplantations showed clearly that clinical methods employed for early diagnosis (first 7-IO days after exposure) of incompatible with life acute radiation injuries of skin, intestine, and lungs are far from being perfect.

Another problem encountered in ARD patients undergoing BMT lies in determining the irreversible stage of myelosuppression. Spontaneous recovery of myelopoiesis was observable in patients exposed to radiation doses 7.0-9.0 Gy and even 10.0 Gy beginning from the 22nd-30th day after exposure. These terms of initiated recovery, in principle, are compatible with life under the conditions of maintenance therapy. Therefore, the hypothesis that long-term, incompatible with life acute radiation pancytopenia occurs already at doses 5-6 Gy, is likely to be incorrect, at least in those cases when dose rates are not very high, as, for instance, in the given group of injured persons.

The experience accumulated in our work enables us to revise seriously the assumption regarding harmless character of BMT in reversible damage of myelopoiesis, i.e. when doses of total gamma-irradiation equal 5-9 Gy. In 5 of 6 patients without incompatible with life non-bone marrow injuries who lived more than a month after exposure, the BMT was accompanied with developing well-defined or occult symptoms of acute secondary disease or reaction of graft rejection, and in 4 cases these alloimmune conflicts contributed to fatal outcome. Acute secondary disease, also promoting fatal outcome in lung radiation injury, was disclosed in one patient of 7, who died within a month after exposure.

Symptoms of acute secondary disease were observable both in cases with HLA-identical and HLA-nonidentical (haploidentical with T-deplection) BMT. In the last cases there was noted short-term engraftment with early rejection of the transplant myeloid portion.

The findings obtained raise a question on feasibility of the so-called effect of mean lethal doses in humans, when transplantation of allogenic bone marrow results in higher lethality than in the exposed control group. The above effect was discovered in 50s-60s in some species of mice, revealed later in some monkeys, though it was not detected in dogs. G.Santos in 1972 in his review describing use of bone marrow transplantation in humans pointed out that "discovery of this effect necessitates taking every precaution in transplantation of bone marrow in cases of accident-induced total irradiation of humans, where the exact doses of exposure may be unknown".

The results of applying BMT for treating patients injured during the accident at CNPP provide the possibility to draw the following conclusions with respect to rules of performing in future transplantations of allogenic bone marrow in humans with acute radiation disease:

I) only HLA-identical transplantations are allowed to be carried out;

2) HLA-identical myelotransplantations may be performed only in those cases when the dose of total gamma-irradiation equals or exceeds 9.0 Gy.

REHABILITATION OF VICTIMS OF ACUTE RADIATION SICKNESS

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Abstract

Two hundred and nine victims of acute radiation sickness following the Chernobyl accident are under observation (first degree - 134, second degree - 54, third degree - 20 and fourth degree - 1).

In 57 (42.5%) of the patients having suffered first degree acute radiation sickness, work capability was reduced by 25%; 9 persons with first degree acute radiation sickness were classified as invalids of the second and third category. In the group with second degree acute radiation sickness, a reduction of the work capability was observed in all cases. In the group with third degree, 100% had signs of disability.

In carrying out rehabilitation and prophylactic measures aimed at reducing social risk factors, considerable attention has been given to publicizing a healthy way of life. At present, professional reorientation has been or is being given to the majority of patients.

An analysis of the results of rehabilitation measures carried out during the year shows a gradual improvement in general health and an improvement in working capabilities. However, the symptomatology of injuries to individual organs and systems remains unchanged.

The development of nuclear engeneering and increase contacts of people with radiation sources enhance the risk of different diseases connected with the ionizing radiation influence. Nowdays, the world practice of nuclear energy application have stored a certain experience of treating the patients with radiation sickness in its acute period. A valuable contribution to the solving of these questions was made by Soviet scientists (L.A. Ilyin, A.K.Guskova, V.I.Vorobiev, A.V.Barabanova, Ye.K.Pyatkin et al.) that allowed to give timely and qualified medical aid to all those, who had suffered during the Chernobyl NPP accident. In the report presented by A.K.Guskova some problems, concerning biological effects of acute ionizing radiation on humans in doses 1 Gy and higher were touched. This paper is devoted to the questions, connected with the elaboration of rehabilitation treatment of patients with acute radiation sickness. With this purpose, in 6 months and 1,5 year after ARS, almost 183 patients got complex clinical, functional and laboratory examination, including radiation anamnesis collection, morphological blood composition test as well as examination of cardio-vascular, respiratory and nervous systems, digestive tract: determination of physical efficiency, sex function and the study of biochemical indices and some parameters of immune system.

According to the data of dispensary observations, 88 % of patients after recovery from ARS recommenced their labour activity. However, 30,7 % had different degree of disablement. For 38,2% the reduction of ability to work wasn't significant: only 25%. The degree of capacity to work depended upon the severity of ARS. However, health condition examination of some patients did not show the absolute character of this relationship.

Table 1 shows, that the majority of patients had changes in different organs and systems.

Table 1. Pathologic conditions in patients after ARS, in different period after the Chernobyl accident

Period after the accident	Neurocirculatory dystonia				Ischemic heart disease	Polyneuropathy
	Cardialgic syndrome	Hyperkinetic syndrome	Asthenoneurotic syndrome	Vegeto vascular dystonia		
6 - 8mon	75,0	45,0	87,6	87,5	25,0	77,1
18 months	61,2	38,3	72,1	80,9	I0,2	82,0

Period after the accident	Chronic duodenitis	Chronic persistent hepatitis	Chronic cholecysto angiocholit	Chronic subatrophic rhinopharingitis
6-8 mon.	41,7	27,1	58,3	87,6
18 months	39,9	27,9	57,9	87,1

Period after the accident	Sex function disorders	
	Copulative	Spermatogenic
6-8 mont.		
18 months	50,8	55,7

The most frequent were functional disorders of nervous system, manifested as neurocircular dystonia and diencephal crisis. The presence of different polyneuropathic manifestations was characteristic.

In 39 % of patients miocardiodystony was diagnosed by clinical and electrocardiographic tests. In 25% ishemic heart disease was revealed, which in most cases had latent course. In the majority of patients digestive organ diseases were revealed: cholecystoangiocholite (50%), persisting hepatitis (27%), gastroduodenitis (41%), erosive gastritis (6%),

Chronic subatrophic upper respiratory tract changes were discovered in more than 90 % of patients, 9 % of patients of this group had mucosal membrane erosion sites, sometimes with ulcerations and haemorrhages.

The data of sex function investigations (I.F.Yunda et al.) testify to its disorders. They expressed in sharp libido reduction, the decrease of spontaneous and adequate erections. Sexopathological disfunctions were formed on the background of astheno-depressive syndrome. The disturbance of hemodynamics play a significant part in sex function disorders, alongside with dienchephalic-copulative disfunction, spermatogenesis changes manifested in spermatozoid quantity and activity reduction, appearance of pathologic forms.

In the majority of cases haemopoiesis had been restored, and only in 7 cases the hypoplastic condition of blood formation had been discovered.

Disorders in blood lypid spectrum were also observed: in 47% of cases - hypercholesterinemia, in 54% of cases hyperlypidemia, that is more than 2 times enhancement of average population indices for a certain age (P.P.Chayalo, et al.)

The study of neutrophyl granulocyte and monocyte phagocytal activity showed the reduction of absorption capacity of these cells and decrease of reserve abilities of phagocyte cells.

Immunological studies testify to the decrease of T-cell immune indices (to 35%), especially T-lymphocytes with suppressor function.

Thus, in ARS patients different degrees of internal organs functional changes as well as disorders of nervous system, sexual sphere, immunological and biochemical status are detected. These changes considerably lowered physical and profeccional activity.

Due to all these, therapy of existing pathologic syndromes, physical condition rehabilitation should be an integral part of these patients treatment. It will be the basis for sufficient working capacity level preservation and ensuring of high quality and vital activity.

With the purpose of health restoration, prevention of delayed radiation effects in ARS patients we have worked out the risk factor system. It includes social, radiological and medical (clinical and functional) aspects. Risk factor conception completely justified itself in preventive medicine and have broad application in our country and abroad. Social factors of risk include hypokinesia, irrational diet, obesity, smoking, alkohol, inadequate professional activity. Radiological factors of risk are: internal and external radiation doses, total and local irradiation. Clinical factors of risk are: different revealed organ and system changes. Functional factors of risk include tolerance to physical loads and working capacity indices.

Popularization of healthy mode of life playes the main role in realization of rehabilitation and prophylaxis measures, aimed at increase of social risk factors. Great attention is paid to the balanced diet, taking into account the facts of obesity, hyperlipidemia, hypertention and digeative organ diseases. In smoking and alkohol prevention explanatory work, reflexo- and psychotherapy are very important. Physical activity is prescribed according to the individual programme. It is aimed on reducing hypokinesia factor, raising of total work capacity, body weight normalization.

Load intensiveness depends on the physical condition, is determined on the basis of clinical data, tolerance to the physical loads and total working capacity.

Presently, professional reorientation of the majority of patients has been conducted. However, job placement process should be dynamic and has to be changed according to the health condition improvement, with the account of adequacy of occupational loads to organizm functional abilities and absence of professional contacts with ionizing radiation.

After 1,5 years complex treatment of ARS patients there is a tendency of reduction of frequency and manifestation of different organs and systems disorders (see table 1). At the same time is noted the increase of total working capacity, tolerance to physical loads, hemodynamic and oxygen supply of the loads. Conciderably reduced number of individuals with unadequate types of reaction on loads: work pulse values lowered, hemodynamic reaction on load became more adequate, changes on ECG are revealed less frequently. However, the quantity of subjective causes, limiting work capacity increased.

1,5 years after exposure cell immunity indices had improved, but they were reliably lower normative values. On this background in 20% of patients were determined antibodies to thyroglobulin, that may be assesses as a sigh of autoimmune thyroid pathology formation.

Thus, in patients after ARS gradual improvement of health conditions is observed. However, the presence of number of diseases and enhanced risk of delayed radiation effects require systematical long-term dyspensary examinations, and complex measures of rehabilitation and prophylaxis.

PROBLEMS OF EVALUATING PUBLIC HEALTH AFTER AN ACCIDENT AT A NUCLEAR POWER PLANT

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Abstract

The Chernobyl accident caused, in addition to external exposure to radiation, inhalation and oral intake of the main dose-forming radionuclides: caesium-134 and 137 and iodine-131. Taken together, the adverse factors emerging from the accident at Chernobyl manifested themselves first and foremost in vegetative dysfunction, disturbances of neurovascular regulation and changes in the reactivity of the immune system.

The significantly increasing migration of the population and its inhomogeneous nature, especially in the groups of reproductive age, are bringing about changes in the structure of the population and in family planning strategies.

In the regions studied, dynamic statistical indicators of the spread of infectious diseases have reflected the general trend in our country, namely towards a reduction of such diseases. In 1986, the frequency of acute intestinal infection dropped in a number of regions by factors of 1.5-8.

In the Ukraine a special clinical register of pregnant women and babies from the regions under study is being kept. The initial document includes 1630 pregnant women. No significant departures from the norm have been found in the course of these pregnancies and births, or in the condition of the new-born babies.

Detailed clinical examination of 416 babies showed that the condition of the vast majority of them at birth corresponded to a score of 7-8 on the Apgar scale.

Examination of the reproductive system in 417 women of child-bearing age did not reveal any abnormalities.

We are now at the beginning of a second observation period, associated with the development of somatic stochastic effects. It will be necessary to carry out further retrospective and prospective analyses of the incidence of disease in various population groups, taking into account age, sex and profession, as well as medical, social, geographical, ecological and other factors affecting the organism.

The assessment of population health status and its changes, in connection with the intensive development of nuclear engineering - is the important component of the system, where general categories, like health and civilization development are closely interconnected. There are a lot of grounds to state these categories are not only closely connected, but actively influence each other. The increase of population health level is one of the preconditions of economical, scientific and cultural progress. It exerts arising influence over the tempo of the scientific, technical and socio-economic progress. At the same time, different economic, social and technical factors not only promote the strengthening og population health, but may cause negative health effects. Thus, both immediate (direct) effect and the mediated (indirect) influence through the majority of pathogenic etiological factors of other nature have to be taken into consideration. The relative value of direct and indirect effects in their summary influences on the human health may be different and must be taken into account. The last circumstance is very important when assessing the possible acute and delayed antropogenic radiation effects of different factors espocially in accidental situations.

The increasing risk level at present on the growing abundance of complicated and powerful technical means. The consequences of accidents, which had taken place on different chemical enterprises and nuclear power plants showed the increase of "price" of any accident, in economic, social and medical aspects. The measures on assesment and control of health conditions, the reduction of negative consequences of the accident must have complex character with the following preconditions:

- registration and assessment of possible risk factors;
- determination of the contingents to be examined, followed and treated;
- selection of the adequate research and control methods;
- establishing of some criteria for decision making and intervention level establishment;

- elaboration of strategy and tactics for bodies and institutions of health service.

Different aspects of the problem were elucidated in other reports during the Conference. In this paper we discuss only the problems connected with a large scale accident.

In approaches to the problem of population healthassessment we underline the importance of classification, correct grouping and interpretation of risk factor. First of all, it concerns ionizing radiation effects. During the accident on the Chernobyl NPP besides external radiation, inhalation and peroral uptake of main dose-forming nuclides (Cs-134,Cs-137) took place. Organotropic properties and significance of the latter stipulated the necessity of thyroid function detailed estimation. Through examination during two years didn't reveal any diseases directly connented with ionizing radiation. At the same time the social, demographic and emotion-psychological factors aquired a substential significance. The accident took place in the densely populated region, that required an immediate evacuation of nearly 150000 inhabitants. It was accompanied by high tension,enhanced excitement, stress and radiophobia among some groups of population. These conditions can cause greater threat for the population health than the immediate danger of radiation effects. The complex of negative factors, caused by the NPP accident, realized among the population, first of all, as vegetative disfunctions, neuro-vascular regulation disorders, changes of immune reactivity. All this may cause cardio-vascular and endocrine pathologies, digestive organ diseases, phychic disorders, increase in the frequency of intectinal diseases and aggravation of their course.

It is notorious that the population health assessment has a complex character. It is based not only on the morbidity rate, but on the indices of physical development and demographic data.

Large scale of the accident in the densely populated region increased the importance of social-demographic processes. The population migration arises immediately. Its irregular character, the most intensive in reproductive age groups led to the changes in population structure. The strategy of family planning changes as well. All this influence considerably the indices of general death-rate, birth-rate and natural population increase.

At the NPP accident not only whole population should be the object of study, but an individual, a family, a cohort, a regional group, etc. The usage of medico-geographic approaches in epidemiological research of non-infectional diseases showed that population formations are possible on the basis of administrative distinctions of territories and regions. However, the population inhabiting the territories of local radioactive fallouts resulting from Chernobyl NPP accident is highly geterogenic. There are distrinctions on sex and age, on ethnic and genetic belonging, on zones of inhabitance and on other risk factors like territorial pathology. Some most conteminated districts are endemic on goiter, which is important for the estimation of I-131 induced alterations. The standardization of cohort observation doesn't allow to eliminate the influence of mentioned distinctions, population heterogeneity, which, according to the UNSCEAR Report serves a source of errors in assessment and interpretation of " dose-effect relationship".

For prospective study of health conditions of exposed population several years' data are needed. The systems containing collection and keeping of information about different diseases spreading, had been being improved in our country for a long period of time. When using these medico-statistical data it is necessary to take into account their dependence upon the patients attendance to medical and prophylaxis establishments.

However, according to the information received, the real spreading of some diseases (e.g. hypertension and myocardial ischemia) is much more than registered officially.

The dispensarization hold earlier embaraces only separate age population groups, professional groups and patients with different diseases, therefore it could not significantly contribute to the general picture. The universal population dispensary system was totally realized in contaminated regions. The brigades of mass medical examination, staffs and regional consultative-diagnostic centres were formed for immediate mass dispensary system on places. The brigades included general practitioners, paediatrists, obstetricians, gynaecologists, endocrinologists, and laboratory assistants. They worked together with territorial public health establishments. Haematologists, oncologists, oculists, neuropathologists, urologists and dermatologists were additionally included into the regional consultative diagnostic centres. Comparison of the results of total medical screening carried out by qualified specialists among the population with retrospective information, based on the personal complaint, may lead to the increase of registered data and to erroneous conclusion on pathology frequency increase. These mistakes were made on the initial stage of works with respect to hypothyroid goiter. However special investigations didn`t discover a considerable difference between the studied and controlled districts. Thorough examination of the adult population of contaminated regions allowed to discover the significant frequency of latent diseases, e.g. cardio-vascular, diseases of central nervous, respiratory and digestive systems. Their spreading 3-5 times exceeds the officially registered data,based on population attendance. However, these deviations are not observed for strictly controlled types of diseases, first of all, infectional and oncological. In controlled regions the dynamics of statistic data of infectious spreading indicated the tendency to reduction, common for our country. In 1986 the frequency of acute intestinal infectious diseases reduced 1,5 - 8 times in a number or regions. The rate of virus hepatitis reduced nearly all over the country. In 1986 the frequency of respiratory-virus diseases in some districts had a rising tendency, but had monthly seasonal peculiarities. In droplet infection group epidemic process dynamic peculiarities with the increase of morbidity level in 2-4 years remains. The example of effective immunization is childhood epidemic parotiditis morbidity. In a number of regions its rate reduced 5-8 times during 4 years.

Malignant tumor morbidity level in the investigated regions approaches the normal distribution with respect to an average indices. In some regions transference of blood-forming and lymphatic tissue cancer frequency from the 3-rd to 5th place was marked. Indices range between maximum and munimum levels was not large. Territorial differencies in malignant diseases quality remain stable in time. Morbidity on certain nozologic forms coinside with general tendencies inherent for the whole country as well as for republics containing the most contaminated regions. Among the children population of controlled regions in 1986- 1987 there were not registreted any extra leukosis cases, i.e. the spontaneous level was not overcome. At present it is too early to make a conclusion about any oncologic effects connected with the Chernobyl accident. The epidemiologic investigation experience testified the possibility of their manifestation in 5 years.

Very important for population health estimation is distinguishing of the most vulnerable groups, critical subpopulations, requiring special attention, immediate and complete prophylaxis measures, treatment and dispensary observation. These subpopulations include pregnant women, newborns, children and teenagers.

In Ukrainian SSR special clinical scientific register of pregnant women and newbornes from the controlled regions is formed. Its entry document contains 164 clinico-laboratory indices. Totally 1630 pregnant women from the controlled districts were observed. Those, who were irradiated in time of pregnancy hadn't any significant disorders in pregnancy course and delivery, in fetus and neonate state. Perinatal death index and congenital anomaly frequency in this group did not differ from preaccident values. The indices characterizing immune and reproductive system blood conditions haven't changed too. Among women exposed before conception the complex dynamic examination discovered some increase in obstetrical pathology: pregnancy frustration frequency has increased in 1,5 - 2 times, late toxicosis, premature birth and bleeding during delivery. According to the prenatal diagnostics data there were 5% of placenta pathology (hypotrophy, destructive changes). Estrogene secretion in fotoplacent complex changes were observed. However " critical " levels, testifying to fetus intrauterine hypoxia or sincitiotrobas irreversible alterations were indicated neither in blood nor in urine of pregnant women. Indices of cell and humoral immunity, studied in pregnancy dynamics were in physiological standard.

The revealed distinctions between two groups of pregnants to some extent confirm the maximum radiation effects for the primary stages of pregnancy: in pre-implantation period and in period of organogenesis. At the same time the frequency of congenital malformations in contro led contingents did not increase and remain on the level, corresponding to spontaneous at preaccident period (about 0,3 %).

The thorough clinical examination of 416 newborns showed that the condition of majority of them at delivery time was corresponding to 7 - 8 mark of Apgar scale. A small number were born in asphyxia of 1 - II stage as a result of their mother's extragenital or obstetric pathology. Two children were born with malformations and one prematurely born. Some of newborns had immune system disbalance, expressed in insignificant reduction of T-lymphocyte level and B-lymphocyte level increase; enhancement of immunoglobulin M content, which is probably, connected with adaptation accomodative mechanisms tension. Incorporations of any significant radionuclide quantities was not discovered in newborns.

The investigations of reproductive function of 417 women in fertile age of different professional groups (from the controlled regions) showed no pathologic changes. Hormon indices of ovary activity, adrenal gland hypophysis, thyroid gland, humoral and cell immunity were identical to control group.

1200 children from the controlled regions were examined according to the specially designed unified scheme. The instrumental, immune, hormone and other laboratory methods were used during the examination. In comparison with the control group, examined in 1980-1986, the healthy children of this population had no significant deviations in investigated organs and systems. Clinical picture of recurrent and chronical unspecific lung diseases (106 children) and chronical digestive diseases (186 children) did not differ from those of preaccident period. At the same time in children with bigger radiation loads a tendency to hypoimmune condition formation was observed. That may have caused more frequent respiratory virus infections in this group. Besides, in this category of children the increase of asthenoneurotic syndrome was noticed.

During 1986- 1987 in regions with higher levels of radioactive contamination the thorough control of population health condition continued. No changes in distribution of investigated people on health groups in comparison with control were observed.

Freguency of haematologic deviations fits the normal distribution function, which is peculiar for healthy contingents. Sick- and death rate study according to the materials of complex examinations didn`t discover significant changes in comparison with the preaccident period. It should be mentioned that systematic examination of population health condition and radiation situation in the controlled regions, confirmed high effectiveness of the undertaken protective and prophylaxis measures.

Summing up our observations, we can state that at present, among the exposed during the Chernobyl accident population there are no diseases directly connected with the ionizing radiation. But it doesn`t mean that the accident had no influence on population health. We suppose, that very important is investigation of vegetative disfunctions, so-called vegeto-vascular dystonia. Somatic effects of combined effect of low radiation doses and other factors, observed during the Cherobyl accident are of great importance as well.

Nowdays we enter the 2-nd period, connected with the development of somatic and stochastic effects. Based on the experience of the health condition studies of Japaneese A-bomb victims, we can expect appearance of leukosis in 2 years after exposure, mammary cancer in 5 years and other tumours (e.g. thyroid gland, lungs, digestive organs) in later period.

Therefore today we must focus our attention on revealing risk factors and precancer fprms. Results of total medical screening of exposed population are very important for the future control and prognosis of health conditions, forecasts of radioinduced somatic effects and their distinguishing from spontaneous ones. For these aims it`s necessary to conduct profound retrospective and prospective sick-rate analysis among different population groups, taking into account age, sex and professional peculiarities as well as medico-social, geographic, ecologic and other factors, affecting human health.

PSEUCHONEURОТIC DISORDERS ASSOCIATED WITH THE CHERNOBYL ACCIDENT

Yu.A. ALEKSANDROVSKIJ

Abstract

This survey relied largely on random selection. As a rule, the attention of the specialists was directed to people with certain specific complaints.

Psychogenic disorders observed in the area of the accident at the Chernobyl plant were followed and studied by a team of specialists from the USSR Ministry of Health, beginning on 29 April 1986. According to the nature of the observed stress effects and of the resultant psychic disorders, it was possible to delineate three periods: first the acute period of the disaster from the time of the accident, lasting about 10 days until completion of the evacuation of the population from the danger zone (5 May); second the intermediate delayed period, the period of comparatively early consequences (from 6 May to October 1986); and third, the period of remote consequences.

In the course of the year, 1572 people were examined.

The data available indicate that the psychogenic disorders observed after the Chernobyl accident can be regarded as the consequence of a single process, the dynamics of which are determined on the one hand by the characteristics of the emergency situation and on the other by the traits and the degree of preparedness of the people involved. The special nature of the stress situation in all three periods - the threat to health - gave rise to certain characteristic clinical observations, primarily a high degree of somatization and hypochondria. An understanding of the psychological disorders affecting those who lived through the Chernobyl accident, and of their effects on the work capability and pattern of life of people at various stages after the accident, has made it possible to develop and implement a complex and refined system of prophylactic and medical measures.

Psychological overstrain, arising in the life-threatening situations may cause psychic disadaptation with its different manifestations in psychotic disorders and the breaches of non-psychotic character. The knowledge of frequency, clinical structure and dynamics of physical disorders arising in extreme conditions, allows to organize adequate treatment and prophylaxis either in the place of life-threatening situation development or during the subsequent stages of victims evacuation.

The events on the Chernobyl NPP were an example of extreme situation in which we observed staged development of psychogenic effects in numerous contingents of population involved in life-threatening situation.

The acute threat to their life and health at the 1-st stage of the accident was followed by the chronification of life- threatening situation, including additional stress factors (the loss of home, property, changes in their mode of living etc.)

The study of psychogenic disorders in the accident zone had been carried out by a team of specialists from the Ministry of Public Health (USSR) since 29 April I986. The psychiatrists and psychologists included into the group, had two essential tasks:
(1) to study the character, structure and dynamics of the physic disorders observed;
(2) to organize, and if necessary, to conduct treatment-prophylaxis measures directed to the revealing and timely treatment of patients with psychic disorders.

The peculiarities of stress influences and the distinctive features of psychic disorders induced by the latter allowed to point out 3 periods:

1) The acute period of disaster: started since the moment of the accident and continued approximately for 10 days, up to the end of evacuation from the dangerous zone. (May 5). The main stressogenic influence was the threat to life and health, connected with the possibility of radiation injury.

2) The postponed period ("the period of early effects") started since May 6 and continued up to the October 1986. At this time the inhabitants of the accident area, NPP personnel and liquidators were deployed in villages remote from the accident point 60-80 km. The conditions of everyday life, life-threatening situation at the working places, the uncertainty in future life and labor guarantees, the loss of a house, property, changing of the living mode- turned out to be " sub-acute" stressogenic factors, which determined the extremety of the situation.

3) Since the moment of putting the new shifting settlement into operation and provision of the evacuated people with resi-

dences and occupations the 3-rd period began. It is called "the period of late effects" and can be characterized by the apprehension of possible radiation injury development (especially for parents worrying about their children's health. It expresses itself also in hard adaptation to the new mode of life and work, subjective attitudes of certain groups of victims about insufficiency and unequality of social assistance.

During one year 1572 persons were examined: 554 of them were reckoned in 1-st period, 416 in 2-nd and 602 in 3-rd. The selection for examination was random. As a rule, the specialists choose patients with different specific complaints. Taking into account, that psychoneurological examinations hadn`t been conducted for the whole accident zone population, the presented data don`t allow to discover common epidemiological regularities of the observed psychogenic disorders. The present report does not contain analysis of development tendencies and the course of neuro-psychic disorder in acute radiation syndrome patients. We suppose, that on all the stages of the accident situation development the specialists had examined nearly all the individuals in the critical zone who had progressive psychotic disorders. The pre-clinical manifestations including acute stressor and adaptation reactions were of non-psychotic and as a rule transitory character.That's why in many cases patients didn`t consult specialists. The clinical psychopathological method was the essential one; psychodiagnostical and psychophysiological methods were also used, as well as medical documentation studies.

The analysis showed that during the formation of psychic disorders and conditions of psychic disadaptation in the period of development and liquidation of the consequences of the Chernobyl accident certain tendencies were revealed.

At the 1-st stage the extreme stress effects have been developing during several days and were connected with the vital basis of existence, and as a result there have formed relatively uniform reactions, generally determined by fear and anxiety expressed at different levels.

The outward expression of stress reactions in the majority of cases were in this period analogous to the first stage stress reaction and were expressed by " stand-still" responce- the reduction of moving activity, or by hyperdynamia - the analogue of " escape". Developing according to the typical stages, described in literature, fear of anxiety didn't reach psychotic level, except for rare cases. They formed under the influence of available information and in the conditions of total absence of any concrete sensor effects. It gave the possibility to prevent panic by the interference of correcting influences. These psychotic disorders marked in the acute period, were determined by reactive psychosis (peculiar for highly hysterical persons having some knowledge about the consequences of radiation effects and exaggerating them in the actual situation. In some cases were reactively provoked aggravation of existing psychotic disorders. The frequency of psychosis was insignificant for the numerous contingents of evacuated people and those, who took part in reconstructive works. It yields to the frequency of acute psychotic disorders,marked in natural calamities and accidents where staggering factor is " visible" (hurricanes, fires, earthquakes etc.).

During the postponed period the reactive psychosis were observed in rare cases. During " the period of late effects" they were not registered at all. Alternative dynamics was established in the frequency of non-psychotic psychogenic disorders. During the 1-st and the 2-nd periods the number of patients in neurotic condition remained unchanged, but in the 3-rd period arose significantly. To some extent, it occurs because in the 2-nd and 3-rd period of the psychic disadaptation functioning the peculiarities of a personality as a whole are of a great value. It can be connected with the chronification of stressogenic effects. During this period neuro-psychic activity " sensitized " by the previous extreme effects was under the powerful influence of so-called "second calamity "- the loss of a house, property, separation with relatives, difficult everyday life.) The indicated psychogenic effects were lengthened in time and have 2 qualitative characteristivs, peculiar for psychological mechanisms of psychic adaptation and disadaptation. On the one hand- this was the vague resolution of the situation in time, on the other - understanding and insurance in happy end, as guaranteed by the state. This 2-nd peculiarity has stipulated the mobilization of adaptation mechanisms. It also significantly postoned the development of psychogenic disorders on the level of shallow, clinically non-structured as a rule and extrapersonal astheno-affective conditions. These conditions, which caused the disorders in physic activity were determined by a sub-acute health threat subjectively endured. Its stressogenic manifestations were decreased by the system of protective measures and limitation of working time in the dangerous zone.

In the 3-rd period there is a subjectively significant health-threatening factor on account of being on the contaminated territory during the accident which is decontaminated nowadays. This factor stabilized in a way, chronified, came into the structure of ordinary life and this made possible to revise the situation intellectually, as well as personal feelings and emotions. Stress chronification, the lack of information about its length, prognisis, real health effects and the possible measures of elimination - all these factors determined "overstrain and demobilization of psychological adaptation mechanisms". Together with enduring non-specific psychogenic disorders in this period, personal, specific forms of disadaptation began to prevail, which in the 1-st and the 29nd periods were observed only in rare cases. However, like during the whole situation, at certain stages of the disaster an anxious tension remains. At the same time depending on personal features, somatic burdens, presence of exogen hazards somatic-effected depressions develop as well as persistent radiophobias and psychosomatic diseases; latent organic disorders may be decompensated, psychopathic manifestations begin to form.

Alongside with the described psychogenically provoked manifestations, at all the stages of the situation development was marked a number of persons with transitory adaptation reactions of non-psychotic character, which, as a rule, recovered completely. Their development depended upon insufficient preparedness for the works in concrete, extreme conditions, unusual physical and psychological overloadings, to say nothing about psychogenic factors, peculiar for each stage.

Represented data show that psychogenic disorders, observed during the Chernobyl NPP accident can be classified as a result of uniform process. Its dynamics is determined, on the one hand - by the peculiarities of extreme situation, on the other - by personal characteristics and the degree of preparedness. It reflects the common conforming of the state of psychic disadaptation development in extreme cases. It is necessary to point out that represented data reflect certain tendencies in accordance with the psychegenic peculiarities and form of psychic disadaptation.

During the period when the magnitude of the effects and the tempo of their development are objectively surplus, simple reactions (like anxiety and asthenia) prevail, but the individual reaction forms play the minor role. When stress becomes chronic and may be classified as " life obstacle " - the individual reconstruction acquires special significance. The originality of stress situation during all the periods (health threat) stipulated a number of clinical peculiarities of observed disorders, first of all enhancement of somatic and hypochondriac manifestations. They are accompanied by vegetative polimorphic disfunctions, and asthenic symptomatics had an evident "organic shade" (amnestic disorders, absentmindedness,understimation of the situation). It should be marked, that professionally trained specialists, having a great experience of work in extreme conditions, did not as a rule suffer from neurotic reactions and disorders in spite of their responsible work. These disorders are peculiar to incompetent people, having no experience of work in extreme conditions. It shows once again the importance of preliminary training for the works in complicated conditions.

The revealed peculiarities of psychic disorders in the contingents involved into the Chernobyl accident (population and liquidators) and the influence of these facts on the vital activity and occupational attitudes allowed to work out and put into practice the differentiated system of necessary treatment-and-prophylaxis measures.

During the first period, the specialized medical assistance was rendered only for those, who required it. It was directed at the discovery, cupping off and extraction from the critical zone of individuals with acute psychotic conditions. During the same period for many inhabitants of accidental areas tranquilizers were prescribed especially for those, who felt development of the neurological reactions, the appearance of psychogenic disorders, insomnia.

Nootropil and bemitil were recommended for those, who took active part in the liquidation of the accident consequences. The somnolent tranquilizers were recommended for periods of rest.

Since the second period consulting, diagnostic and psychoterapeutic measures playedthe leading part in the treatment, prophylaxis and psychoterapeutic assistance. In the districts where the rescue workers lived the complexes of psychoemotional relief were opened, as well as in some medical enterprises of the region. In one of the stationaries the department of neurosis was opened. A powerful rehabilitation center for the participants of reconstructive works began functioning in Kiev. The majority of residents from the accidental regions and the personnel of the NPP received there a number of health maintaining procedures, including psychotherapy. Simultaneously, the medical personnel from the territorial psychoneurological hospitals were enlisted to the work with the evacuatèd population. The known methods of group and individual psychotherapy were used as wide as possible together with reflexotherapy, physical therapy, generally maintaining praparations, psychopharmaceuticals etc. The mentioned medical measures had been conducted differentially, according to the conditions and peculiarities of life and occupation.

During all the stages of accident consequences liquidation psychologists and psychiatrists paid much attention to singling out the causes, inducing neurotic reaction. Among these causes the major ones are: insufficient and wrong information about the nature of the radiological situation, especially in the first period of the accident (which raise a wave of panics); the late information about financial compensations, bad organization of life conditions and other psychologically hurting circumstances. Timely analysis of social, psychological and socio-hygienic caused gave us the reason to address different instances with requests to immediately eliminate them.

As a result of undertaken measures psychoemotional tension and neurotic disorders were eliminated considerably and microsocial contacts and ability to work improved.

Thus, treatment-and-prophylaxis of neuro-psychic disorders during the Chernobyl NPP accident demanded wide and multiple psychoneurologist`s activity directed to the solution of medical and medico-social problems. Evidently, in all life-threatening situations, the activity of a psychologist and psychiatrist will be much wider than their usual diagnostic and treatment activity.

This is one of the Chernobyl lessons, urging corresponding training of specialists.

STATE OF THE PITUITARY AND THYROID SYSTEM IN CHILDREN AT VARIOUS TIMES AFTER EXPOSURE TO RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT

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Abstract

A clinical/laboratory examination was made of children from the age of 1-14 years from the area of high radiation. The examination was carried out on a continuous basis, beginning in the first half of May 1986 and is still in progress.

At no stage was there any clinical evidence of thyroid dysfunction, but, in a significant proportion of the children an increase in the size of the thyroid gland was noted. In May and June 1986, 77.5% of the children had a first or second degree enlargement of the thyroid gland. At the same time, there was an increase in the level of T_4 in the blood: 85.20 ± 7.36 nmole/L to 348.33 ± 38.26 nmole/L.

In the subsequent stages, a gradual normalization of these parameters was noted. No other significant functional or organic disorders of the pituitary-thyroid system were detected.

It is known that during the first year after the Chernobyl NPP accident iodine radionuclides were a principal factor of population internal irradiation. These radioactive nuclides were uptaken through the respiratory organs as well as through biologic chains with the food stuffs.

The radioiodine accumulation in thyroid gland caused the exposure of this organ. Absorbed dose of children was somewhat higher than that of adults due to the relatively higher iodine accumulating capacity of their thyroid glands.

According to the modern conception, the injury of thyroid gland under the conditions of irradiation is observed in children more often than in adults. Besides, it is also necessary to take into account that the possible outcomes of thyroid gland diseases are considerably more serious for children. This circumstance necessitates particularly intent attention and the study of dynamics of thyroid gland functional state in children, involved in contacts with ionizing radiation.

We have carried out clinical laboratory examinations of children from 1 to 14 years old from the zones of enhanced radiation. The examinations began in May 1986 and are beingcontinued.

We estimated the functional state of thyroid gland on total and free thyroxin, thyrotrophin, thiiodothyronine, thyrocalcitonine and antibodies to thyroglobulin in blood by the radioimmunological method with the help of standard kits.

The examination was carried out in dynamics, in five stages:

1 stage	May 1986 - July I986
2 stage	October 1986 - December 1986
3 stage	March 1987 - May 1987
4 stage	October 1987 - December 1987
5 stage	March 1988 - up to now

During the examination of children on every stage there were not revealed any symptoms of thyroid gland disfunctions. But it is necessary to note that on the first stage of examination we observed the increase of thyroid gland dimensions in a certain part of children. 6-8 monts later we observed a 1,5- 2 times reduction of thyroid gland increase frequency in these children. We can interpret the increase of thyroid gland, which took place during the first months after the accident as transitory vascular and secretory reaction in responce to the radiation influence. On the first stage of the examination in children, who had been in contacts with the sources of ionizing radiation, we observed the increase of average values of total thyroxin content in blood.

In order to clear up the reasons of absence of thyrotoxicosis clinical syndroms at the high level of total thyroxin we determined free thyroxin concentration. It is known that the realization of hormonal effect is defined to a considerable extent by the level of free hormone. It was found that the content of biologically free thyroxin was within the limits of normal variations or exceeded them insignificantly. Here we have to underline that we determined free thyroxin level only in children with the high concentration of total thyroxin in blood.

On the second stage of the examination the tendency to normalization of thyroxin level in blood was revealed, and by the third, fourth and fifth stages the hormone content reached the normal values.

The analogous picture was observed for another thyroid hormone - triiodothyronine (its increase on the first stage of examination and normalization of its level in the subsequent periods).

One of the most important and direct indices reflecting the functional state of thyroid gland is the content of thyrotropic hormone of hypiphysis in blood. In general the average level of thyroprophin in the blood of observed children did not differ from the normal values.

At the same time on the first stage the thyrotrophin concentration in blood of some examined was slightly reduced. This reduction is obviously connected with the increase of free thyroxin level in blood of these children according to the principle of negative inverse relation.

And on the contrary, we observed in a part of children in that period the transitory increase of thyrotrophin level in blood. The latter we explain by the manifestation of stress reaction. The confirmation of this supposition is the activation of the hypophysical adrenal system, revealed at the first stage of examination.

It should be supposed that simultaneous multi-directed influence of two factors on the secretion of thyrotrophin: stress and hyperthyroxinemin levels of the content of this hormone in blood.

On all the next stages of examination the everage content of thyrotriphin in blood and the individual indices did not differ significantly from the norm.

Side by side with this, analizing the individual indices (in the whole mass of children) of thyrotrophin and thyroxin levels in blood, in 92 children we revealed simultaneous increase of thyrotrophin concentation and decrease of thyroxin concentration, i.e. so-called laboratory hypothyrosis. All these children, without exception, were subjected to extended clinical and laboratory examination, as a result of which the diagnosis of hypothyrosis was confirmed in 12 cases. That does not exceed spontaneous frequency of this pathology.

It should be supposed that the effect of radioiodine absorbed by thyroid gland depends not only on its quantity but also on the age of a child. In this connection we had analized the state of hypophysial thyroid system depending on the age of child. On the first stage of examination we revealed the inverse dependence between the age of a child and the total thyroxin content in blood. This dependence remained to some extent on the second stage of examination.

We also should take into account the fact that physiologic augmentation of thyroid gland is meet with more often in pre- and pubertal periods. That is why these contingents of children need long-term clinical laboratory examination in dynamics.

Therefore, to estimate the role of separate components capable of causing subsequent thyroid gland pathology it is necessary to use multi-factor analysis.

We had revealed in the part of children the increase of thyrocalcitonine content in blood, which normalized in 6 months.

We can suppose that the transitory increase of this hormone level is connected with the activation of thyroid gland S- cells by incorporated radioiodine.

Side by side with the hormonal investigation of functional state of thyroid gland we determined the content of antibodies to thyroglobulin. On the first stages the increase of level of antibodies to thyroglobulin in blood was determined in 5% of the examined and then - 7,6%. Though the observed growth is negligible, at the same time taking into consideration the importance of this index for the prognosis of autoimmune pathology of thyroid gland, thorough control of this index in dynamics is necessary.

Taking into account the anatomic proximity of thyroid and parathyroid glands we consider it necessary to investigate the functional activity of parathyroid gland, too. The parathormone concentration in blood on the first stage of examination was considerably enhanced in the majority of children. 12 monts after the accident the parathormone level in blood of children became completely normal. It is possible that the revealed augmentation of parathormone content in blood is connected also with the parathyroid gland activisation as a responce to incorporation of iodine in thyroid gland.

In order to clear up the structure of thyroid gland the ultrasonic investigation of the part of children was carried out. Any considerable changes in thyroid gland were not observed.

Thus, summing up the afore said, we have to note that any expressed pathology of thyroid gland in children after the contacts with ionizing radiation were not revealed. In the part of children the augmentation of thyroid gland, the increase of thyroid hormone, thyrocalcitonine and parathormone levels in blood took place. 6-12 months after the accident the normalization of indices characterizing the function of hypophysial thyroid system and parathyroid gland were noted. At the same time only two years passed after the accident. Taking into account the data of world literature we consider that the children subjected to radiation influence need the further thorough clinical-laboratory control for the timely detection of thyroid pathology possible in this situation and prescription of adequate therapy.

MEDICAL CARE DURING THE RADIATION ACCIDENT (^{137}Cs) IN BRAZIL, 1987

G.D. SELIDOVKIN

Abstract

The report describes the activities of diagnosis, prognosis and treatment of overexposed individuals during the radiological accident of Goiania in Brazil. In particular it describes the handling of 17 individuals who suffered acute radiation syndroms.

After summarizing the development of the accident the report describes the radiation injuries of people, the biological dosimetry methods used for the diagnosis of doses and the methods for decontamination. The treatment and the response of the patients is also described in detail.

The group, consisting of I7 individuals with different symptoms of acute radiation syndrome had been formed as a result of stealing and destroying of a highly radioactive cesium containing source in the city of Goiania (Brazil).

During the I,5 months nearly 250 individuals were examined. In 25 of them, by the methods of physical dosimetry the signs of contact with radionuclide were discovered, especially the skin contamination. At the first stage 26 individuals of this group were hospitalized on the suspition of radiation sickness, but in a short period of time, 6 of them avoided this diagnosis.

Further examinations allowed to cancel the diagnosis, regarding 3 more patients.

The most injuried individuals (at first IO, then another 4) were moved to the Navy Hospital Marsilio Dias, Rio-de-Janeiro. The scheme of accidental situation, included into the sickness histories, didn'n satisfy the comparison with clinic and anamnestic data. Therefore, retrospectively, but quickly enough, we had suggested another version adopted by the Brasilian specialists.

I3 September. An unemployed Roberto found a metal installation in the oncological hospital that was closed at that time.

Together with his friend Wagner, he removed the parts of this installation to his home, where kept them up to the I8 September. With the help of Wagner, Roberto dismantled the defence of the installation and extracted a cylinder with the length about 30 cm and the diameter about IO cm (weighting 25-30 kg) containing I37-Cs. After that, Roberto broke the hermetically sealed installation by the screw-driver. At the same day, the metal parts of the installation and the cylinder were removed to the Devair's scrap metal depository and remained there untill 2I September.

Devair's emploee Ademilson had been processing the metal and probably 20 September was subjected to the first irradiation dose.

After selling of the metal parts, in the evening of 2I September Devair discovered a cylinder in the centre of his warehouse, enaming strong blue glow. He brought it into the house and used as a night-light.

For more than six days, the cylinder, containing the radionuclide was standing on the I,2-I,5 metre heigh chest of drawers, I,8 metre away from Devair wife's bed. Maria-Gabriella Fereira, his wife, spent all her spare time in this room.

23 September Devair ordered another man, Israel, to disassemble the cylinder, but the attempt to do it with the help of hammer failed.

24 September Devair's brother Ivo came to visit him and with the screw-driver separated the pieces of the source, put them into the pockets and brought it home. He gave his 6 years old daughter Leide one of the pieces at meals. Probably, she ate the particles of the source together with food. At the same time, his I4 years old son Lucimar received another piece of source. When Loise Odette came to see him, Ivo smeared her neck with the powder, moreover, some crumbles got on her breast, hips and stomach. Then Ivo went to Loise's husband Cardeck and thus, some particles of cesium got into Cardeck's bed, where he slept.

The remainders of the source Ivo scattered in the yard of his house, part of them got into the rooms.

25 September Devair continued the disassembling of the source. Ademilson, obviously, helped him, taking the cylinder in his hands. Devair scattered the particles of cesium in the yard, some of them got into the house. Those people visiting him took the parts of the source as souvenirs. At the same time, another Devair's son Adson Batista was irradiated.

Devair's friend Adson Fabiano also received the practicles of the source, brought them home and shared with Odesson, and the next day with his brother Ernesto.

27 September. The medical personnel, where the victims applied for help, suspected the possibility of irradiation and Devair ordered Geraldo to bring the cylinder for dosimetry. The man was carrying it about half-an-hour in the right shoulder.

30 September. Maria-Gabriella Abru, who had slept in the same room came up to the moment of hospitalization of her daughter and her husband.

Thus, the indicated people and some other were subjected to external irregular irradiation, their skin was contaminated by nuclide with the possibility of its incorporation. In the centre of the city had formed 7 comparatively large zones contaminated by radionuclides and about 50 minor ones. Thus, in Roberto's house were discovered 500 mCi of radiocesium. The signs of cesium were found on the tree tops, IO-I5 metres height, standing 250 and 800 m away from Devair's house.

The common activity, by the discovered quotas (the passport data missing) are estimated as approximately I370 Ci of I37 $CsCIO_3$. Medical aid to the injured was organized according to the existing in the world common rules. Pre-hospital aid was provided by the Brasilian physicians and, taking into account their own abilities, all the persons, suspended of the radiation damage, were hospitalized for the observation, totally - 26 patients. Another 29 were followed out-patiently up to the final regection of suspition of radiation syndrome.

Both hospitals (in Goiania and Rio) are hospitals of common type. They were accomodated for deployment of the patients with combined radiation injuries. The walls and the floor were covered with plastic pellicle. Skin integuments were treated in the wards. Radiation protection of the personnel was carried out since the first day of receiving the patients by permanent clothes changing and using special plastic and paper wear.

For diminishing the second absorption of Cs from intestine all the patients since the first day of the hospitalization received "Radiogardas" (Hail Ltd., West Berlin) preparation of "Prussian blue" type, binding and at the same time transfering cesium into the insoluble compound: in Goiania IO-I2 gm per day, in Rio 4-6 gm per day. The enployment of the preparation allowed to increase cesium excretion in 2-4 times without decrease of its concentration in urine, i.e. naturally, it had not any influence on the nuclide metabolism in the basic deposition places and, correspondingly, in blood.

With the purpose of strengthening of radiocesium excretion with urine, the patients received the diuretics (furocemid), which increased the urine volume and with the unchanged same concentration of nuclide increased its total withdrawal.

The internal Cs I37 irradiation occured obviously as a result of the radioactive compound swallowing.

The final account of the internal irradiation doses, according to the data of biophysical study of the patients in Brasil, was conducted by Gusev I.A.

It was shown, that the doses of internal irradiation, exceeding 0,05 Gy (30 days after radiocesium consumption) had only 9 individuals. The comparison of these doses and those, calculated by the cytogenetic methods, showed that the internal irradiation composes no more than I5-30% from the kariologically assessed value (except for Leide, who had about 50%).

Thus, we come to the conclusion, that the levels of internal irradiation couldn't cause the development of direct biological effects and actually all the early manifestations had been determined by the irregular, total, external irradiation together with local radiation injuries.

The analysis of information about the quantity of nuclide excreted with urine showed significant fluctuations (about 8 times). If we except Leide's case, avarage biological half-life for the group of 9 patients having the major nuclide contamination (according to Gusev and Dementiev) was 20-30 days, i.e. the usage of diuretics together with "Radiogardas" hastened the nuclide excertion in 2-3 times.

The principles worked out in the clinics underlined the prognosis of expected acute radiation sickness.

For the assessment symptoms of primary reaction as well as the rare data on hematologic studies in the first illness decade, and the cytogenic analysis of periphery blood lymphocyte culture were used. IO from I4 patients (Rio) were noticed to have primary reaction symptoms, such as nausea and vomiting.

The possibility of postponed symptome development and the disperancy of its intencity in the time of momentanious irradiation, were suggested taking into account the prolonged influence character and the experience of total therapeutic irradiation, conducted among the clinic's patients. The retrospective analysis showed, that the periods of vomiting appearance were 3-6 hours after the beginning of irradiation at severe ARS, those with median ARS had it in about 8-I2 hours.

Anorexia could be marked as well but much more rarely: in two patients with severe ARS and in one - with median one.

Up to the end of the first day in 3 cases frequent water stools occured. Only in Leide's case it could be assessed as an irradiation reaction (symptome) as she had the diarrhea relapse, she had melena, as well.

Four patients (2 with severe and 2 with median ARS) felt sick and tired during I-2 days.

Nobody had any significant temperature rise.

The analysis of hematologic data allowed to predict that in all cases, a dose of gamma irradiation doesn't exceed 6 Gy, excluding the threat of dangerous bone marrow syndrome of ARS. It rejected the idea of bone marrow transplantation.

The dynamics of laboratory investigations corroborated this opinion and allowed to group the victims according to the neutrophyl account changing. This test is the most exact characteristic of the bone marrow syndrome. The conducted grouping was in appropciate correlation with cariological investigations. Therefore, we can conclude that as a result of Goiania accident (Brasil) there were 5 cases of acute radiation sickness, 3 patients received median dose and the rest 9 - slight damage of blood formation.

Haemopoiesis had restored in all the cases, except for Leide's, who died during medullar radiation aplasia. 3 other victims died after the beginning of haemopoiesis repair - in 32, 34 and 38 days.

Except for the period of abortive rise, the neutrophyl dynamics was quite ordinary. At that time in blood platelets were mainly defined, which is probably connected with the lower affectation of commited and morphologically recognizible cells. At the same time, stem cell death was similar at one-event irradiation.

In 8 cases stimulating macrophagal and granulocytic cell factor was used. The factor is glicoprotein (molecular weight I4000), regulates granulocytic and macrophagal proliferation. The factor is considered to be strictly specific, acting through the cell surface receptors, independent from other mediators. There are data about other stimulating factor effects. As experimental studies showed, the factor stimulates of granulocytes yield as well as that of monocytes, eosinophyles, to some extent megacariogenesis, but it has no influence on erythroid and lymphoid cells. Moreover, the factor potentiates phagocytosis function, stimulates prostaglandin yield, activates plasmonogene.

Taking these properties into account, as prof. Gale has recommended, there was a decision to use the factor for the acceleration of peryphery blood cell repair.

In all the cases (except Leide's), where the factor was used, transient growth of granulocyte number was observed. Estimating the action of the factor in cases of ARS, one could observe actual absence of effect on the duration of total agranulocytosis. It can be explained by the peculiarities of bone marrow radiation injury. Cell proliferation kinetics is synchronized by irradiation, and taking into account that factor influences commited cells, some period of time is required for their accumulation. This is the result of repair after dose-dependent radiation myelodepression. The patients with severe and middle degrees of bone marrow syndrome during the period of granulocytosis received antibiotics according to the adopted scheme, worked out for bone marrow transplantation. The treatment begun after receiving of bacteriological inoculation or after appearance of the obvious symptoms of infection development.

As a rule, at first, were used antibiotics of aminoglicoside and cephalosporin groups , later amphotericin B was added; the patients received selective intestine decontamination.

All the patients with different degree of BMS (numbered 8) in its climax had infectious complications. 5 of them with severe form of BMS had stomatitis; in 2 other cases - esophagitis and pharyngitis.

The frequency of especially serious infectious complications development in two subgroups was similar: pneumonia - 2 cases in each subgroup; and sepsis, documented by the blood microflora inoculation - 3 cases in each subgroup. Microorganisms - stimulators: clebsiella - 3 cases; mixed flora: clebsiella + collibacillus - I case, un-indentified (for the mission period), G - flora - I case, staphylococcus and pseudomonas - I case. Two woman-patients had a positive reaction to cytomegaloviruses presence test.

Serious infections were the most obvious causes of patient deaths: 2 individuals in each subgroup.

When the trombocyte level reduced, the patients were prescribed donors trombocyte transfusion. They were received with the help of blood cell separator CS-3000, from one donor for each transfusion.

Hemorrhagic syndrome proper was observed only in 4 cases, moreover, 2 patients had moderate skin hemorrhages; 4 patients - eye sclera hemorrhages; I had blood in excrements, odontorrhagia and musocal oral cavity hemorage, the autopsy revealed subarchnoid hemorrhages that have evidently formed during the terminal period.

Only one patient - Leide - had serious hemorrhage: abundant nasal bleeding, 3 days melena, blood in feces, the autopsy showed minor subarchanoid hemorrhages, and hemorrhagic changes in colon.

Practically all the patients in Brasil had local radiation injuries, expressed in the bullous and desquamative radiodermatitis. But only in 2 cases radiodermatitis covered 20-25% of body surface, in I case - I0% and 3 - 5% in all the other cases. Radiodermatitis located on the open body parts, especially on hands.

Radiodermatitis course at small damaged parts was favourable and finished with complete rehabilitation in I - I,5 months. One can expect benefitial effect of the "Oxopherine" (BRD) on the reducing the period of healing. The preparation, as the authors affirm, favours the development of macrophagal activity on surface of the wound and thus forming better conditions for epithelization and aloe solution as a stimulator.

In 3 cases there was a necessity to make necrectomy of small skin pieces and subcutaneous fat. Wound in 2 cases had healed completely, but one patient had a recurrence of ulcerrous process on the thing after I,5 month.

When the lesions were ample, no healing had occured during 2 or more months. One of the patients was subjected to hand skin necrotomy and on the 63-th day the terminal phalanx on the left hand finger was amputated.

In the patient with radiodermatitis of both forearms and hands the necrotic process intensification up to the end of the 3-rd week caused considerable intoxication on 25-26-th days. Investigation with Tc-pyrophosphate incubated with autoerythrocytes took place on the 25-th day, confirmed the cessation of blood circulation in left hand. On the 26-th day the left forearm was amputated on the boundary of middle and upper third part. It liqudated intoxication and lowered considerably body temperature. The wound healed by the first intention.

All the patients were discharged from the hospital up to the end of the 3-rd month. Only two of them had the leukopenia clinical symptoms and one individual had a residual wound postulcerous process on the thigh.

DISCUSSION

P.V. RAMZAEV (USSR)

First of all, I would like to note the success of clinicians who had struggled with radiation sickness in treated individuals who had received doses of 600 rad and more. The fact that many of them survived testifies that radiation medicine has now appropriate means that give the possibility to increase the former values of lethal dose (LD) in 2 times.

Second, another ground for optimizm is the fact that there were no victims among lay population, moreover, there are no grounds for anxiety about future. The latter statement is based on the following: according to the latest concepts adopted by International Commission on Radiation Protection (ICRP) and UNSCEAR there is no radiation damage expected at the doses lower than 50 rem. However, even at rather low doses of exposure caused by accidental irradiation there are huge resources in the USSR for reduction of total irradiation dose. Thus, only for 3-5 min natural irradiation from radon and its daughters exceeds 2rem/year of total irradiation and can reach I6 rem/year for lungs. For this contingent radiation effects connected with the collective radon dose is 70 times higher than the total collective dose from the Chernobyl accident.

My point of view is that as far as the Chernobyl accident is concerned practical health service has no particular interest but for enlightment work. The system of this work is developed, for instance, in the Ministry of Public Health of the Russian Federation. On the other hand, Chernobyl has put before us a number of complicated tasks; they concern dosimetry, medical radiobiology, radiation protection, etc. These problems have, in my opinion, international character. That is why I consider it expedient to make a proposal about organization in Kiev on the Base of All Union Scientific Centre of Radiation Medicine the International

Centre on Medical Aspects of Nuclear Engineering. In the new conditions of Perestroyka in our country this proposition will be accepted by authorities.

C.E. BRANDAO-MELLO (Brazil)

MEDICAL ASPECTS OF THE GOIANIA ACCIDENT

In September, I987, two unemployed men removed a sealed Cesium-I37 (^{137}Cs) source from a radiotherapy center in Goiania, Brasyl. Over the next several weeks a large mumber of persons came into contact with the source. Exposed persons were evaluated clinically and haematologically on September, 30, I987 at the triage center in Goiania.

Based on the severity of acute radiation syndrome (ARS) and skin lesions, patients were treated at different medical sites: primary level at local dispanceries, second level - General Hospital of Goiania and tertially level - Radiation Medical Unit at the Navy Hospital in Rio de Janeiro.

Aproximately 249 persons were exposed. I29 had moderate to severe internal and external contamination. 79 persons were managed as out-patients. Fifty persons required dose medical surveillance. 20 of these 50 were hospitalized of whom thirteen developed severe bone marrow depression. Eight received GM-CSF (Granulocyte Macrophage Colony Factor). Five received supportive care including prophylactic antibiotics, anti-viral and anti-fungal drugs and transfusion of red cells and platelets.

Four patients died during the first month after the accident from complications of ARS including bleeding (2) and infection (2). Internal contamination due to inhalation, ingestion or absorption of ^{137}Cs was assesed "in vivo" by total body counting and "in vitro" by radiochemical analysis of biological specimens. Persons with substential contamination received "Prussian Blue" at doses of I,5 to IO g per day:

Presently most victims are well; one remains hospitalized with a severe radiodermatitis of the right thigh.

A perspective programme of following-up is in progress.

T. SHARMA (India)

SHORT AND LONG TERM CYTOGENETIC AND GENETIC STUDIES OF THE POPULATION AFTER THE CHERNOBYL ACCIDENT

I am sure, cytogenetic and genetic analysis are going on after the Chernobyl Accident but in the present conference no data have been presented. I sencerely hope the data will be published in near future as well as in later dates and when the data are generated.

It is very important what has been emphasised in this meeting but it will be of no less importance to try to investigate the cytogenetical and genetical aspects as well. It will be desirable to do proper cytogenetical and genetical analysis and, if necessary, in collaboration with talants and expertise available from different countries. The Chernobyl accident was not only of the USSR, it was of whole mankind.

POPULATION STUDIES, PUBLIC HEALTH AND ALL-UNION REGISTER

MEDICAL DEMOGRAPHIC CONSEQUENCES OF THE CHERNOBYL ACCIDENT

N.I. OMEL'YANETS, G.I. MIRETSKIJ,
M.M. SAUROV, V.F. TORBIN

Abstract

A demographic study was made of the population evacuated from the 30-km zone around the nuclear power plant and of the population living in areas over which the radioactive cloud passed and over which the plume was formed.

For the farmers evacuated from 11 655 homes in the Chernobyl region, 7000 new houses, built in the Kiev region, had already been provided within 5 months of the accident, and by the summer of 1987 another 5000 houses were available.

A study of the resettlement of the population carried out a year after the accident showed that more than 60% of those evacuated continued to live in the regions from which the evacuation had taken place; about 5% were resettled in other republics, and 20% within their own republic.

Chernobyl NPP accident unlike the accidents which had taken place in other countries, was characterized by certain peculiarities. Among them are: release of fussion products beyond the bounds of the NPP-site, contamination of the enviroment by the radionuclides by stages, the involvment of large groups of the population into the consequences of the accident. About I thousand square km of the territory was contaminated, the population from this area was evacuated, some people continue to live in the regions with technogene enhanced radiation background.

Low exposure doses of population as a result of the accident, and well-known data concerning the influence of ionizing radiation on the human body don't allow to single out immediately after the accident the primary damages of organs and systems or to estimate the appearance of diseasses in exposed population. At the same time the study of demographic situation resulting from the accident on the territories adjacent to the zone influenced by Chernobyl NPP realeases is of a certain theoretical and practical interest. The present report is devoted to the results of the investigations on this problem.

The object of the study was the population evacuated from the 30 km radius zone of NPP, and the people living in the areas on the route of radioactive cloud and its trace formation. With regard for the character of accident development the investigated territories were selected: Gomel and Mogylev regions of Byelorussia (north western trace), Chernigov region of Ukraine, Bryansk region of Russia (north-eastern trace), the city of Kiev, Kiev and Zhitomir regions of Ukraine (southern trace). As indices characterizing demographic processes there were studied the character and the degree of mechanic movement of the evacuated population (migration streams, directions of migration, sex and age structure of migrants) and natural movement of the population, living on the named territories (birth-rate, death-rate, natural increase of the population). The indices established during the post-accident period were compared with these of the previous five pre-accident years and also with the All-Union and republic indices.

From the data of the figure I we can see that about II6,5 thousand people were evacuated from 30 km radius zone of Chernobyl NPP, and the majority (7I,6 thousand) from the Ukrainian SSR (Kiev

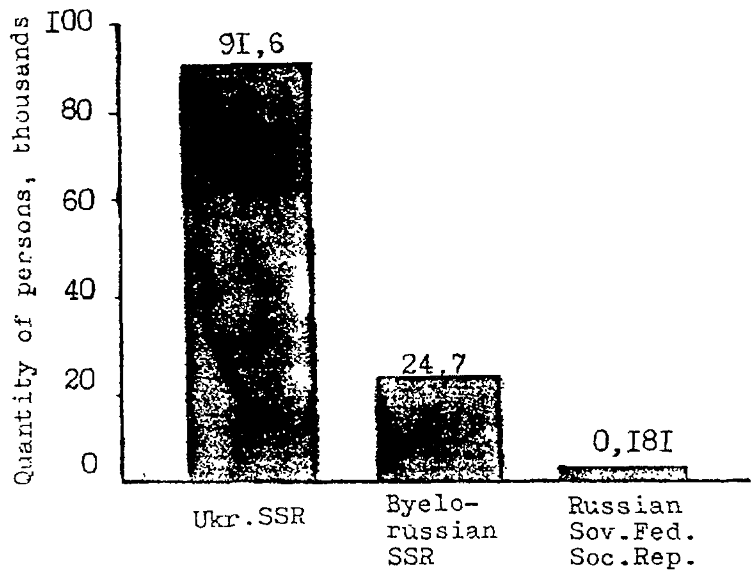

Fig.I. Quantity of persons evacuated from the Chernobyl NPP zone of exclusion.

and Zhitomir regions). The places of evacuation of people on the territory of the Ukrainian SSR are showed on figure 2, from which we can see that the population from 72 settlements, including the towns of Prypiat' and Chernobyl, was evacuated in 5 neighbouring regions situated beyond the limits of 30 km radius zone.

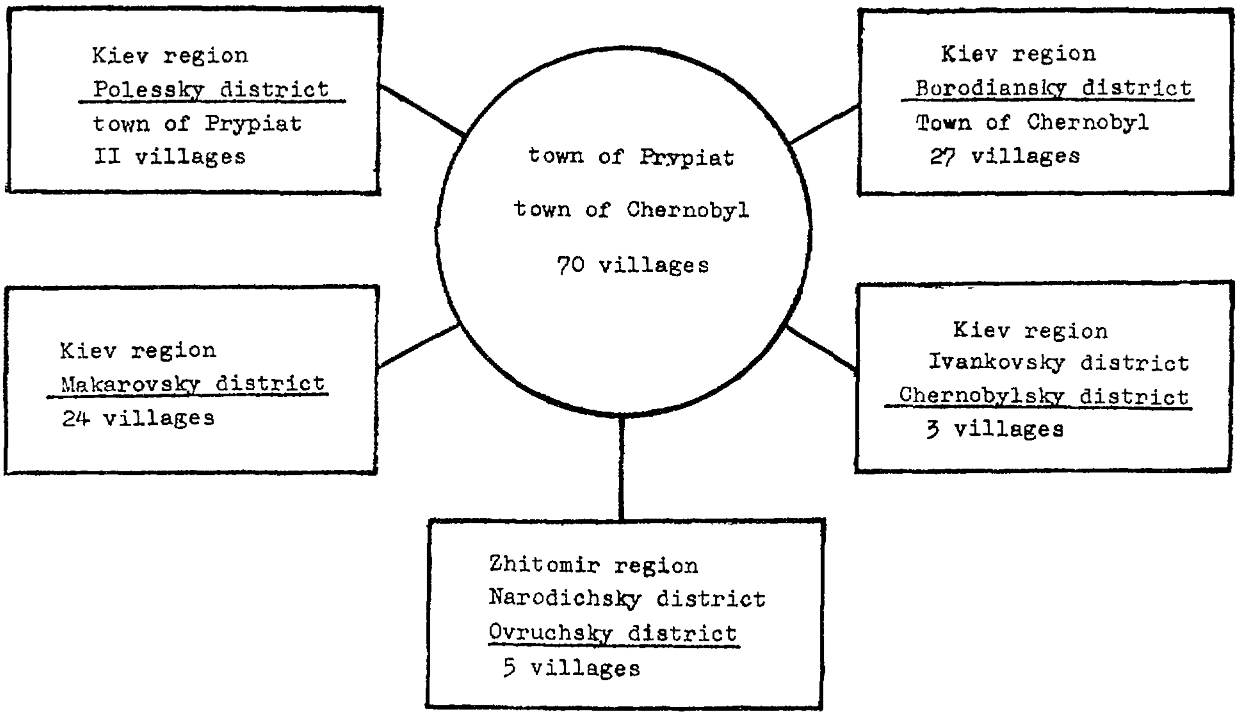

Fig.2. Places of withdrawal of evacuated population from the 30 km radius zone of Chernobyl NPP .

Proceeding from the analysis of current radiological situation the evacuation as a temporary measure of preventation of population overexposure became constant, and was guaranted with the govermental measures on ensuring of the evacuated population with the permanent residence and work, and creation of a follow up system of their health status. In Kiev and Chernigov there were allotted in a short period of time more than 8 thousand flats with modern conveniences for evacuated power engineering specialists. Later they were given 6 thousand residences more.

With the purpose of settling the inhabitants of rural areas who lived in II 665 houses before the accident, it was decided to build the residences mainly of farmstead type. 7 thousand of new houses were constructed already 5 months after the accident, and by the summer of I987 - about 5 thousand of farmsteads and flats. The data about distribution of new built houses are represented in Table I.

Table I. Distribution of apartment houses built for the evacuated population in Kiev region

District, settlement	Number of villages	Number of houses of farmstead type	Number of blocks of flats	Number of flats
I	2	3	4	5
Barishevsky district	7	I630	-	-
Boguslavsky district	I	I46	-	-
Borodiansky district	7	II90	-	-
Vasilkovsky district	4	400	-	-
Vasilkov	-	-	I	I08
Volodarsky district	4	470	-	-
Volodarka	-	-	2	80
Vyshgorodsky district	4	260	-	-
Novosyolky village	-	-	I	60
Zgurovsky district	I	I20	-	-
Zgurovka		I20	4	200
Ivankovsky district	5	520	-	-
Kiev-Sviatoshinsky district	-	-	-	-
Vishneovoye		-	I	200

Table I (cont.)

I	2	3	4	5
Kagarlykski district	3	I90	-	-
Kagarlyk	-	-	I	30
Makarovsky district	I7	2I05	-	-
Mironovsky district	5	540	-	-
Mironovka	-	-	I	I00
Pereyaslav-Khmelnitsky district	5	3I0	-	-
Pereyaslav-Khmelnitsky	-	-	3	I34
Polessky district	-	-	-	-
Polesskoye			3	I34
Skvirsky district	4	288	-	-
Skvira	-	-	I	80
Stavishchansky district	4	390	-	-
Stavishche	-	-	I	40
Tetiyevsky district	I	I85	-	-
Tetiyev	-	-	I	40
Fastovsky district	4	227	-	-
Chernobylsky district	-	-	-	-
Gornostaypol	-	-	2	48
Yagotinsky district	I0	I2I3	-	-
Yagotin	-	-	I	I08
TOTAL	87	I0I84	25	I362

It was constructed in total 87 new villages and 25 blocks of flats in towns and villages. Side by side with dwelling-houses the social objects were built and among them, as we can see from Table 2 - schools, kindergartens and day-nurseries, shops, bath-houses, etc.

Table 2. Social objects built for evacuated population in Kiev region

Objects	Quantity
Schools	33
Kindergartens	46
Shops	3I
Medical establishments	22
Bath-houses	I9
Dining-rooms	I4
Complex reception services	22
Local official quarters	29

Equally with the social problems the legal questions were decided - the evacuated people had the advantage before other citizens in the insurance of job, health and consumer services. The medical follow up of their health was instituted. In order to inform health protection bodies and establishments about evacuated persons in proper time the national information system was created. On its basis is formed the All Union registry of evacuated population, closely connected with the All Union distributed Registry. It will give an opportunity to embrace the evacuated population by the scientific investigations on many aspects: demographic, dose, epidemiologic, clinical, as well as estimate immediate and delayed radiation effects.

The data from the figure 3 show that during the first year after the accident the following system of sottling was formed: about 85% of evacuated remained to live in their own republic, mo-

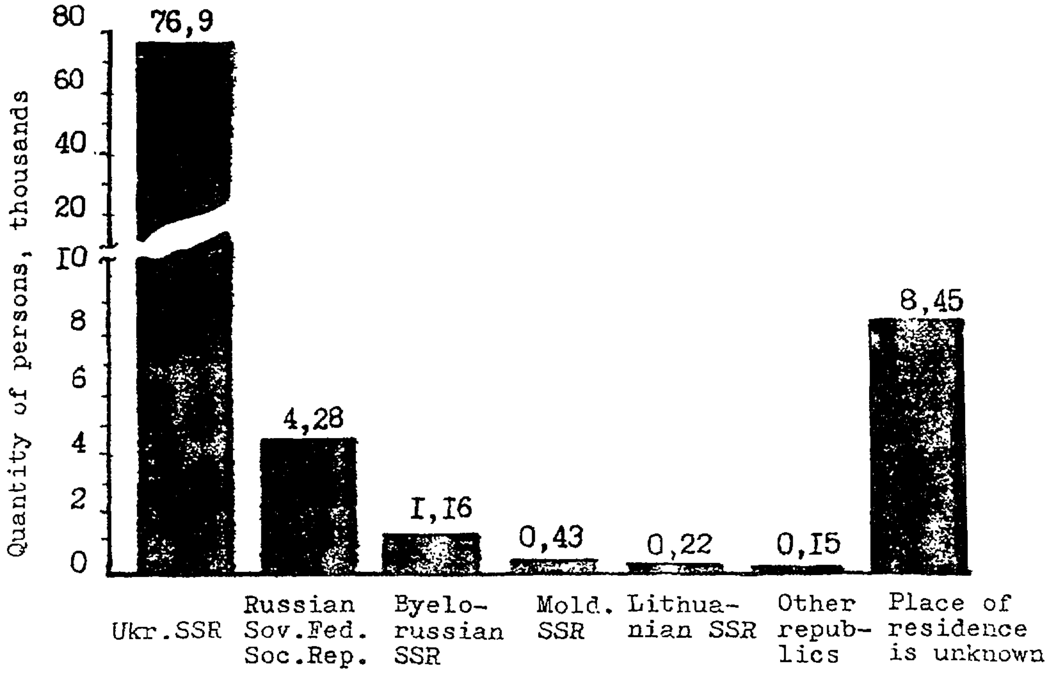

Fig.3. Places of residence of population evacuated from the Ukrainian SSR on the territory of the USSR (according to the data of namelists).

re than 60% of them - in the same regions. About 5% of evacuees were settled on the territory of the country. Up to I0% of evacuated had changed the place of residence once more and we are defining it more precisely now. In the process of migration the deplacements within the settlements, connected with the change of temporary residences for constant ones, prevail. There are also attempts of some evacuated to return home within the limits of 30 km radius zone. These are eldery persons and the persons of old age, who can not leave native locality by force of habit.

According to the data of retrospective observations (fig. 4-7) the territories of the Ukrainian SSR adjacent to the accident zone are characterized by a high birth-rate in the towns and a low birth-rate in the rural areas, and significant scatter of death-rate data. The most inauspicious indices of natural movement of the population were recorded in Chernigov region, where the natural increase was practically absent. At the same time in Kiev the birth-rate was considerably exceeding the average, the death-rate was 30% lower than that in Ukraine, the balance of natural increase was positive. In the Byelorussian zone of the accident, that is mainly agricultural, the indices of natural movement of the population were considerably higher than these of the Ukrainian SSR and approximated the average indices of the country, and mainly due to the high birth-rate. The area of Russia takes the intermediate place among the above named territories according to the investigated indices. For all zones the fluctuations in the indices of death-rate on causes are characteristic. There is a certain dependence of these indices on diseases, when the level of urbanization and medical assistance is important. However, during the recent years (I983-I986) in all the followed regions the growing positive tendencies in demographic indices began to apper; these tendences were linked with the growing popularity of "healthy mode of life".

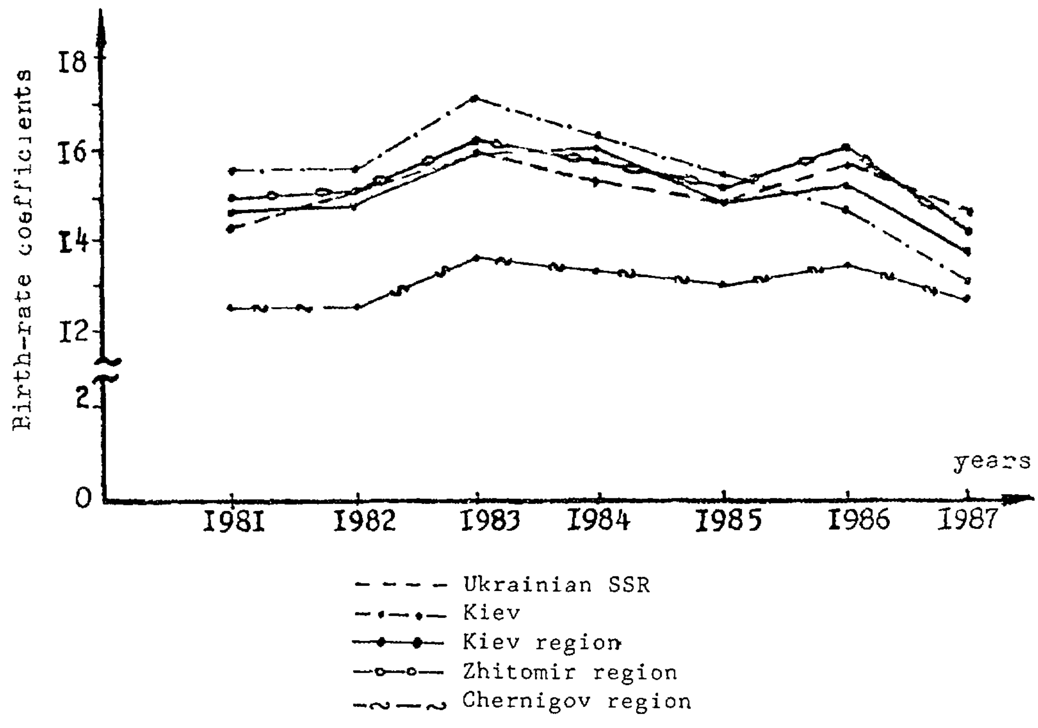

Fig.4. Birth-rate on the territories of the Ukrainian SSR adjacent to the zone of Chernobyl NPP accident(per I000 inhabitants).

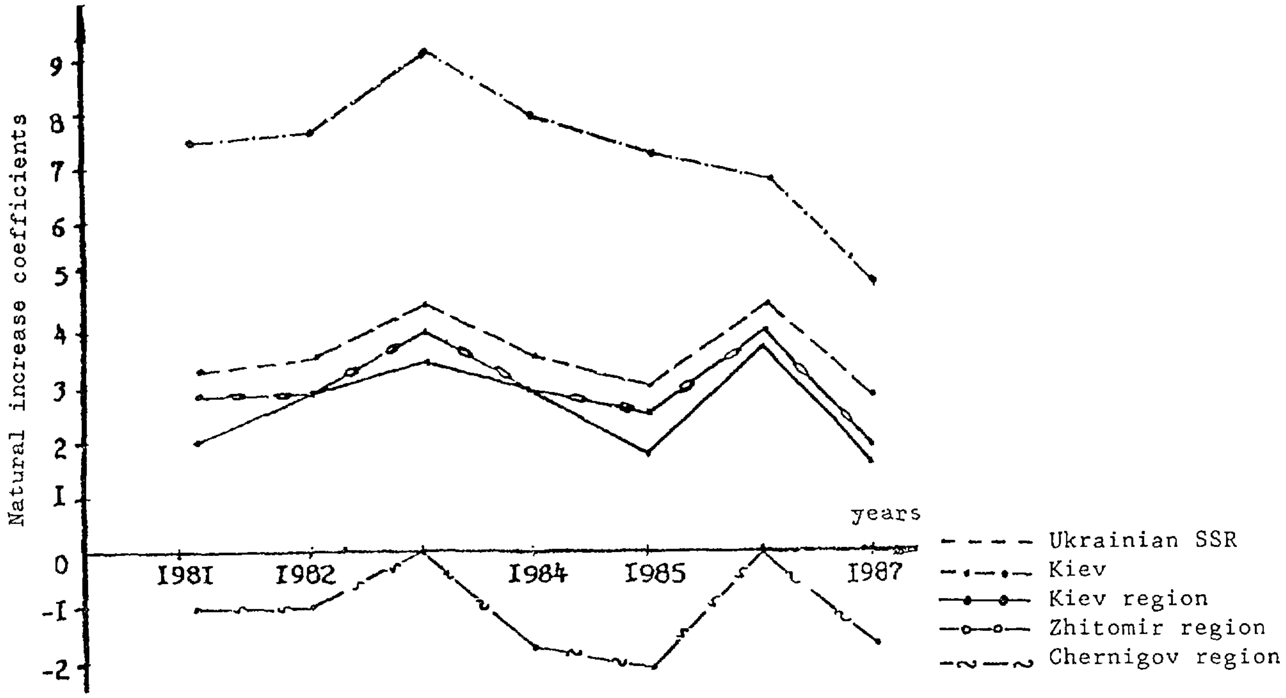

Fig.5. Natural increase coefficients on the territories of the Ukrainian SSR adjacent to the zone of Chernobyl NPP accident (per I000 inhabitants).

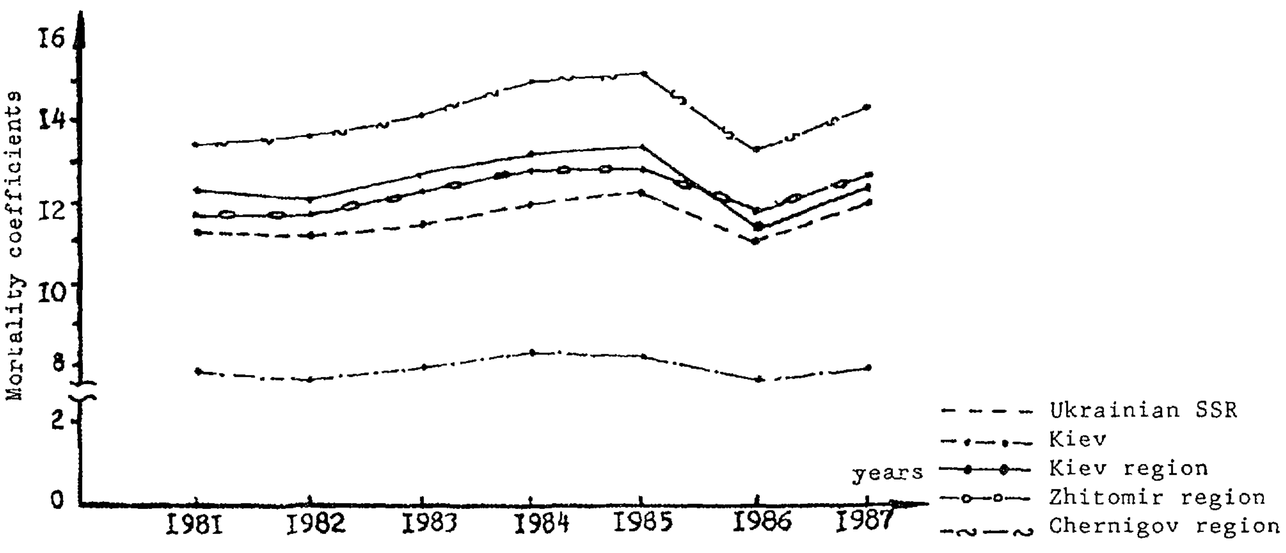

Fig.6. Levels of mortality on the territories of the Ukrainian SSR adjacent to the zone of Chernobyl NPP accident during the period of I98I-I987.

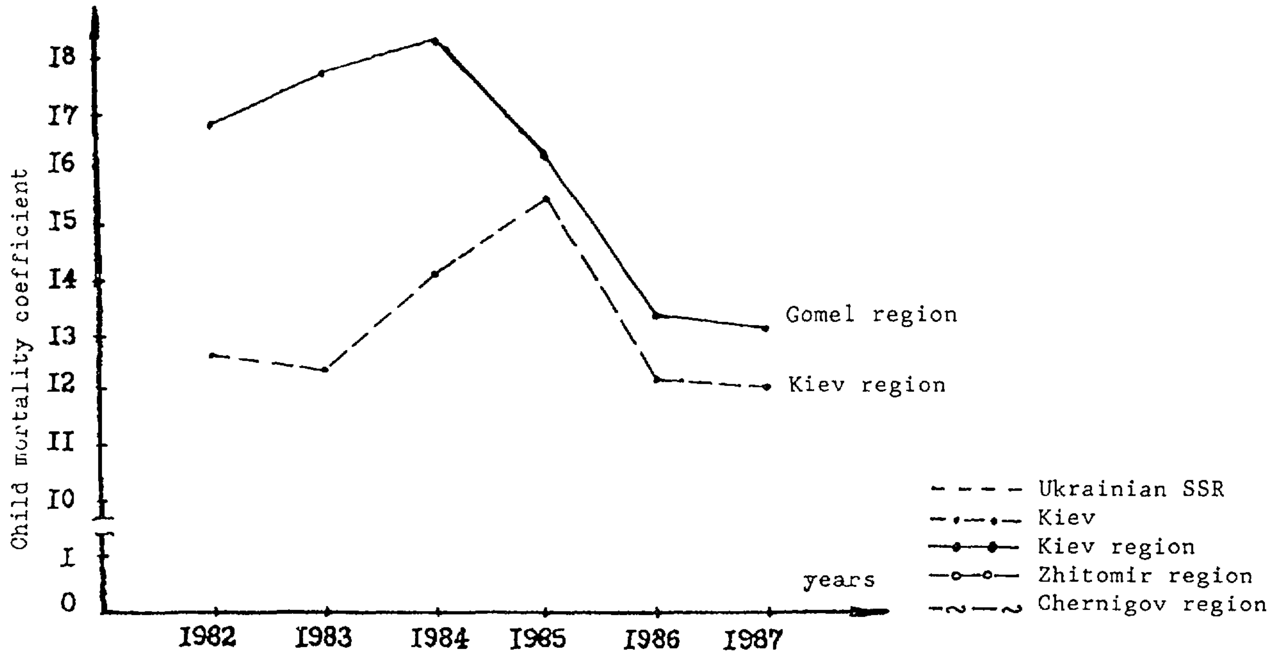

Fig.7. Levels of child mortality on the territories of Gomel and Kiev regions during the period of I982-I987.

As we can see from figure 4, the natural increase of population during the first post-accident year didn't differ from the usual. The considerable changes in the birth-rate and death-rate were not registered, either see the data of fig. 5,6. The exeption were some regions of the Ukrainian SSR, adjacent immediately to the zone of the accident. There the insignificant (8 - 23%) transitory lowering of birth-rate was observed. Having thoroughly studied the sex and age structure of population living on these territories, migration activity of the population, the frequency of abortions, we came to the conclusion that the lowering of birth-rate is connected with the removal of pregnant women for sanitation, with the departure of women of fortile age from these territories and, to a certain extent, with the changes in family planning strategy under the conditions of post accident radiophobia.

As for the child mortality, we can see from figure 7, that since I985 it continue to lower in Ukraine as well as in Byelorussia, though the rate of its lowering slightly reduced.

In the causes of child mortality we didn't reveal any changes in their structure in compairison with the pre-accident period. The outcomes of pregnancy, health status of children born by women who were pregnant at the moment of the accident, we have no grounds to speak about any changes in the population reproduction.

The foregoing data permit us to make the following principal conclusions:

I. Under the conditions of a large scale accident of NPP reactor the evacuation of the population from the zone of ionizing radiation influence becomes necessary. Unlike the large scale accident on other industrial objects, the nuclear accident make the evacuation permanent, because due to the actual radiological situation re-evacuation to the settlements situated near NPP would be hardly possible within the next few years. Evacuation in its turn results in the intensification of mechanic movement of this category of the population, i.e. the change of one of demographic indices.

2. The hightened migration activity of the population doesn't always promote its social well being. But taking into consideration that in connection with the measures undertaken by the state in the new places of residence of evacuated people the conditions of life and work, social and medical services were improved, there is every reason to expect their favourable influence on the health of the people of this category.

3. The NPP reactor accident of large scale and the ionizing radiation influence connected with it don't exert influence upon the principal indices of natural movement of population (birth-rate, death-rate, natural increase, child mortality) during the first post accident year.

ORGANIZATIONAL, METHODOLOGICAL AND INFORMATION ASPECTS OF THE MASS INDIVIDUAL DOSIMETRIC SURVEYS CARRIED OUT IN CONTAMINATED AREAS FOLLOWING THE CHERNOBYL ACCIDENT

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Abstract

The dosimetric surveys carried out after the Chernobyl accident relied on a preliminary evaluation of radiation conditions shortly after the explosion and were backed up by special arrangements on the personnel and organizational side, as well as by appropriate information techniques and methodology.

The calculational part of the work involved the use of mathematical models and a special computer program for the dosimetric calculations. The models include parameters agreed upon by leading experts of NCRP (USSR Ministry of Health) and make it possible to adapt the dosimetric calculations to various situations corresponding to the sex, age, height and body mass of those examined, their whereabouts and type of nutrition in the controlled zone, and the frequency of contact with radioactivity. The computer programs are designed for speedy calculations and allow an assessment of absorbed doses in field conditions (using small computer technology) and in hospital conditions (at different levels of the all-Union distribution register).

The main part of medical measures on population health protection after Chernobyl accident is the timely and adequate dosimetry of all the individuals subjected to radiation exposure.

The main objectives of this examination are:

- Immediate classification of the examined population according to dose risk groups;

- For the groups of enhanced risk, provision of urgent prophylaxis and treatment measures according to dosimetry data;

- Decision making for minor risk groups about the character and extend of protection, prophylaxis, treatment and consequent follow-up;

- Obtaining necessary data for the Registry with the consequent long-term medical follow-up.

In case of inadmissibly high level of radioactive contamination, neccesitating urgent population evacuation, dosimetry is conducted with the aim of immediate estimation of contamination levels of skin, clothes, private things. Through dosimetry examination, including estimation of body radionuclide content and internal doses has to be conducted soon after evacuation of population from dangerous territories.

Irradiation doses from the enhanced gamma-background can be estimated on the basis of dosimetry data of environmental contamination and individual inquest about the behaviour in the controlled area. For the population of permanently controlled zone dosimetry may be restricted by the assessment of the average absorbed dose of external irradiation for a concrete settlement (excluding the territories with high exposure rate gradients).

Besides, absorbed doses of internal irradiation due to inhalation of radioactive substances have to be estimated separately for each case basing on individual spectro- and radiometry and the inquest of examined individuals about their behaviour regime in dangerous zone and the peculiarities of diet. The individual approach is necessary due to the revealed individual differences in internal doses that have the character of lognormal distribution. That is stipulated by both individual peculiarities of radioactive substances metabolism in body, and by the specific features of food-stuff consumption and behaviour in controlled areas, as well as cattle farming, adopted protective measures, local irregularity of radioactive contamination of the territory.

In may I986 and autumn I986 as well as in spring and autumn I987 mass individual dosimetry examinations were conducted, that embraced the population of territories subjected to radioactive fall-outs with relatively low contamination that did not require evacuation. The time of examinations was chosen according to seasonal peculiarities of cattle farming (pasture and stalled cattle keeping) that is the main link in transport chain of radioactive substances from environment to human body. In autumn 1986 and 1987 dosimetry was conducted within total medical screening of the controlled contingents.

Dosimetry investigation was based on the results of preliminary assessment immediately after the accident and had methodical, personnel, organizational and informational support.

The estimation of the situation was aimed at the correct determination of contaminated areas, decision making about population protection, expediency of individual dosimetry examinations as well as at the choise of adequate methodical support with the regard of future works. Situation estimation included determination of external gamma-background, selective measurements of radionuclide composition and environmental contamination level, as well as contamination of food stuffs and corresponding territory quartering. For these and other works connected with the mentioned problems complex working plan was developed and adopted. It included medical establishments, sanitary-epidemiologic service, civil defence boards, research institutes of the USSR and Republican Ministries of Public Health and Academy of Medical Sciences, establishments and institutions of Goscomhydromet and Gosagroprom. Organizational support was provided by the Party and Soviet bodies.

As far as at the acute period of the accident the main danger was that from radioiodine affecting thyroid gland, and the critical group from this point of view are children and pregnants (foetus), in May 1986 this group was subjected to individual thyroid examination. Data obtained were immediately addressed to medical establishments for decision on protective and prophylaxis measures.

Individual dosimetry survey of radiocesium content was started later (autumn 1986, spring - autumn 1987). This examination involved both children (including unborn) and adults. Together with dosimetry total medical screening of the population was launched. Primary medical documents were compiled. Data obtained were entered into a computer database and served as basis for data array of dosimetry information for the All-Union Distributed Registry of individuals subjected to irradiation as a result of the Chernobyl accident.

Methodical support included hardware and calculation parts. Various instruments from laboratory equipment were widely used: multichannel and singlechannel spetrometers, whole body monitors, thyroradiometers and portable field dosimeters. Methods of field radiometry and spectrometry were urgently assimilated to the actual situations, corresponding instructions were worked out and distributed. Significant contribution in medical support of these works was done by specialists from Moscow Institute of Biophysics (USSR Ministry of Public Health) and Leningrad Institute of Radiation Hygiene (Ministry of Public Health of Russian Federation).

On contaminated territories measurements were conducted, as a rule, in stone or concrete appartments. That decreased gamma-background significantly. Measures were taken against radioactive contamination of appartments.

Most important methodical points are: thorough preliminary and then periodical calibration and intercollation of all the involved instruments on radioiodine and radiocesium on phantoms of thyroid gland and whole body, containing standard ammount of activity. Positive was the experience of calibration with voluntary phanton-carriers who had uptaken standard ammount of radiocesium and who were regularly checked. This calibration was conducted in field conditions for various body positions. The involved equipment, means of dosimetry, phantoms, were checked and calibrated by special expert commission, formed on the dercee of the USSR Ministry of Public Health. Age dependance of calibration factors and shielding coefficients as well as their dependence on body weight and position were determined with body physical phantoms and calculations - with specially developed adoptable mathematical age-dependent phantoms of whole body and thyroid gland.

The methodical support includes mathematical models and dosimetry calculation software. The models include parameters coordinated by the leading experts of NCRP (USSR Ministry of Public Health) and allow to adopt dosimetry calculations to various situations corresponding to the age, sex, height, weight of the examined individual, the character of this diet in the controlled area, the duration of his presence in the zone of radiation effects. This software provide rapid estimation of absorbed doses both in field (small computers) and stationary conditions (on different levels of the All-Union Distributed Registry).

Personnel of dosimetry examinations includes specialists and specially trained in spectro- and radiometry individuals. Moreover, every medical team must include at least two dosimetry specialists and one specialist in dosimetry registry. One specialist on computer methods is capable to process the data provided by 7-IO medical teams.

Organizational support is mainly connected with transport means, immediate connection between the teams and the centre busy with active data processing, decision making, detrmination of schedule of works, intersubstitutability of specialists, instrument service.

The experience gained makes possible to conclude that the principle point at mass dosimetry examinations is informational support of the work. Taking into account the low level of radiological knowledge in lay population, with the aim of prevention and prophylaxis of unreasonable radiophobia, elusidative works have to be launched together with dosimetry. Information of mass media is also of great importance.

The following criteria of this informational support can be singled out:

- reliability and uncontradictory character of information, which implies preliminary expert assessment of all the published data without any exclusion as well as formation of centralized information centre;

- competence and independence of informators, necessary participation of specialists, preferably physicians, confident for the population;

- regularity and immediateness of information, regular publishing of bulletins, constant information in mass media, fixed information time on TV and radio; fast reaction on any changes in the situation, prevention of rumours;

- Openness of information, that is possible by helding regular brieffings, meetings of specialists with lay population, consultations of "question-answer" type, including anonimous.

The above information is of great importance because the negative consequences of radiophobia may turn out highly essential from both medical and social points of view.

DATABASE FOR A SYSTEMS ANALYTICAL APPROACH TO STUDYING THE MEDICAL ASPECTS OF THE CHERNOBYL ACCIDENT

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Abstract

The main elements of the program data base were the all-Union distribution register and the SDACHA computer system (Chernobyl accident data system) which ensured reliable functioning of the PRIORRA expert system [acronym stands for "taking of optimum decisions in the event of a radiation accident"].

The development of criteria for the optimum selection of countermeasures follows three paths - medical, economic and social - and is based on a regulatory document entitled "Criteria for taking decisions or measures to protect the population in the event of a reactor accident".

The long-term program for studies of medical aspects in the Chernobyl accident has a general task to develop and realize on the base of Chernobyl experience effective therapeutical and prophilactic measures aimed at protection and support of human health in large radiation accidents.

An active component inherent to the task determines a due consideration of the multifactor character of the effects resulting from accidental consequences. In these circumstances the use of a systemic analysis has been essentially justified.

As a system we shall consider detriment characterized by harmful effects on the population caused by the accident in Chernobyl (investigations of its scope and specific features, possibilities and methods of its decrease, assessment of the efficiency of measures directed at its decrease or prevention which were already realized or are in the stage of realization and development of a complex of highly effective measures for protection of the population in large radiation accidents).

The difficulty of describing the system under study is determined by the large number of acting factors, objects against which the effects are directed and types of reactions of these objects to the effects.

As the main factors of action it is necessary to consider the following: proper radiation effects resulting from the Chernobyl accident; information on the fallout and harmful radiation effects on to the human health causing the so-called radiophobia; social, economic and hygienic measures for the liquidation of the consequences of the accident, practical actions of public health authorities and special organizations in the course of investigation and liquidation of the consequences of the accident. The objects against which these factors act are various populational cohorts: those evacuated from the zone of CNPP ; those living at the territory contaminated by radioactive fallouts; members of the working teams for eliminating the consequences of the accident and individuals who were not exposed to radiation but who are sure that they were; authorities of public health and research medical establishments. Reaction of the system to the action of the above given factors realizes itself in the following negative phenomena: social and demographic events, mass radiophobia, increased morbidity not caused by radiation effects; diversion of resources and means of public health to the search of diseases induced by radiation. The positive reactions of the system include early diagnosis of diseases by mass screening; accumulation of experiences useful in case of radiation accidents.

The study of this system is impossible without a reliable information base. The main directions in its development are:

1. Creation of the data bank for investigating regularities in the formation and determination of individual and collective radiation doses to the population and members of the working teams eliminating the consequences of the accident.

2. Creation of the data record for individuals exposed to radiation as a result of the Chernobyl accident to provide a long-term automatic registration of these individuals, their children and future generations, radiation doses and estimates of their health and its changes.

3. Collection, analysis and systematization of investigation results of the consequences of the accident and experience of their elimination, i.e. effective use of all informational resources.

4. Provision of efficient management of the research and practical work for the liquidation of the consequences of the accident.

The All-Union Distributing Register (I) realizing p. 2 of the directions and the computer system СДАЧА (in Russian) (Data System of the Chernobyl Accident) which must provide pp. 1, 3, 4 of the directions have become central components of the information base in the studies.

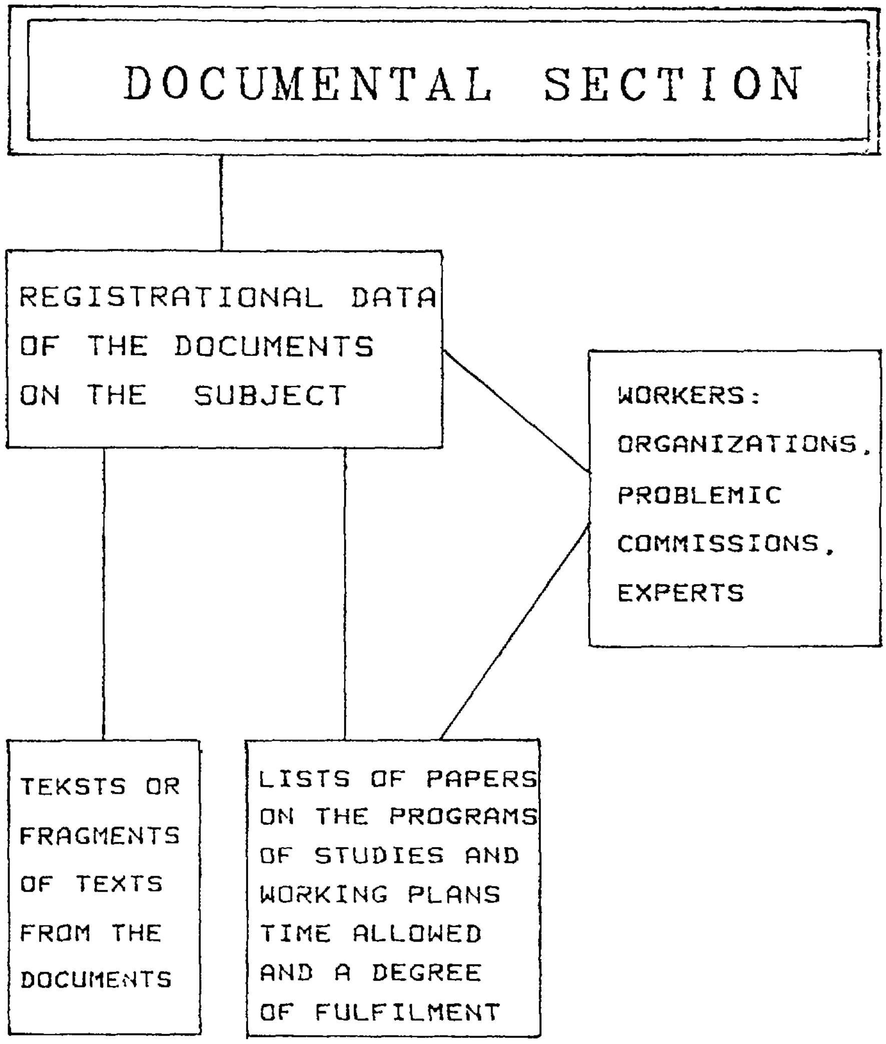
The data base (DB) of the system СДАЧА includes organizational (scope and types of measures and examinations performed) instructional and methodical (methods and approaches used in carrying out examinations and measurements) and factographical information on all recorded data from the inputs and outputs of the system.

These information objects are divided in two specific types: factographical and documental sections.

The documental section of DB (Fig. 1) includes the following subsections: registrational data of the documents; working plans; contents of the documents; responsible workers.

The above mentioned sections include (respectively):

- title, authors, key words and registrational data of all documents on the subject;



1. Outcoming data of the documents on the subject
2. Responsible workers:

   organizations
   problemic commissions,
   experts

3. Texts or fragments of texts from the documents
4. Lists of papers on the programs of studies and working plans. Time allowed and a degree of fulfilment

FIG.1. STRUCTURE OF THE DOCUMENTAL SECTION OF THE SYSTEM СДАЧА.

- programs, plans, time allowed, stages of work and degree of its fulfilment;

- most important text sections of the documents including regularities, instructions and methods;

- information about organizations and experts - participants in the work.

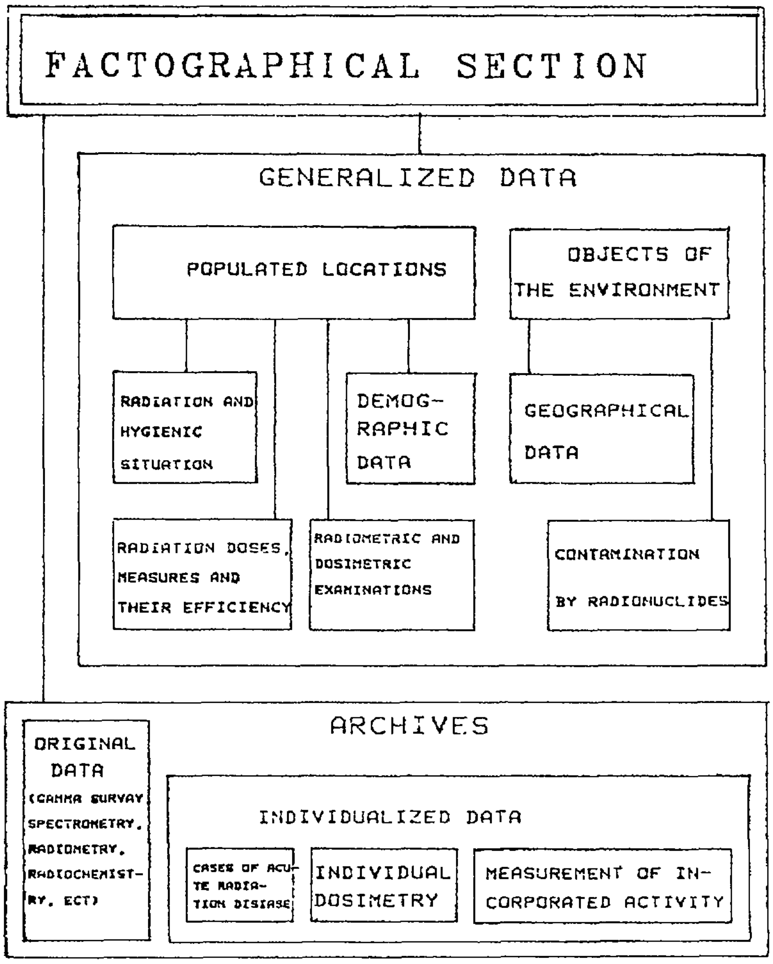
During one-two years the whole number of documents included into DB will reach 1-1,5 thousands (without about 500 papers of the foreign authors).

In creation of the factographical section of DB specifications of the accumulated information fund and long-term planning of the work were taken into account.

Data sets on radioactive contamination of soil, vegetation, environmental objects and food products were created. They also included data on measurements of the incorporated activity, individual dosimetry, health state of some population groups and on other indices. The systems of information computer analysis were widely used for therapeutical purposes in such fields as hematology, biochemistry, immunology and drugs. Models developed earlier were used for integral estimations of radiological consequences of the accident.

Finally the following structure of the factographical section was accepted (Fig. 2). Generalized data were records for 5000 populated locations in the USSR, (including "clean" - control ones) rivers and other water reservoirs. The complete list of items in this Register was not determined, so it can be enlarged to 1-2 thousands of items in accordance with reguirements of a systemic analysis of the subject. The items concerning populated locations, in particular include:

- administrative and territory divisions, size of the population and its groups, date and year of the measures performed, dynamics of changes in gamma dose rates;



1. Factographic section
2. Generalized data
3. Populated locations
4. Objects of the environment
5. Radiation and hygienic situation
6. Demographic data
7. Geographical data
8. Radiation doses, measures and their efficiency
9. Radiometric and dosimetric examinations of the population
10. Contamination by radionuclides
11. Archives
12. Original data (gamma survey, spectrometry, radiometry, radiochemistry, etc)
13. Individualized data
14. Cases of acute radiation disease
15. Personal dosimetry
16. Measurement of incorporated activity

FIG 2. STRUCTURE OF THE FACTOGRAPHIC SECTION OF THE SYSTEM СДАЧА.

- dynamics of changes in radionuclide contamination density in soil, vegetation, food produced within the controlled area, mean doses of internal and external irradiation of the population as a whole and its occupational and age groups, results of medical examinations of the population, etc.

In case of necessity the distribution characteristics of these values are given. The individualized subsection of DB includes the lists of individuals from the population and proffecional workers with the results of their dosimetric examinations. In this case the list of indices will be enlarged only at the expense of an addition of more detailed data on incorporated activity and radiation doses. Other subsections of the lower row contain archives of the original data including radionuclide content in samples of soil, vegetation and food, results of detailed radiation and hygienic examinations, etc.

Data supply to DB of the system СДАЧА is performed either on computer carriers from the data banks of organizations and individual research workers or from scientific reports, articles and other materials. The structure of the information obtained is changed in accordance with the registration objects in DB.

The problem of excess information is solved by an analysis of data supplied for treatment and by optimization of the information relations. It should be noted that by a number of indices characterizing the first days after the accident excess of the information in DB is not ruled out. It makes it possible to increase credibility of data and to accelerate their treatment.

Software provision of DB allows one to increase without any limit nomenclature of the data stored in the factographic section, to form depending on the character of an inquiry separate documents or sets of text documents, tables of any form, charts and schemes. Besides the existing programs for statistical treatment the system СДАЧА will be provided with the fund of programs for calculating dose values, radionuclide transfer, algorythms of essential factor selection, multifactor and cluster analysis.

To sum up, the computer system СДАЧА provides the effective control of working plans, the search for references and methodics in certain scientific directions, reliable storage of factographic data on the subject; it also provides:

- effective access and possibility of computer treatment of the generalized information;

- systematization and generalization of data on medical effects of the accident;

- possibility of using data for estimating the effects of not projected accidents at plants;

- centralized provision of the All-Union Distributing Register with all data for calculating individual radiation doses.

The existing experience of handling the problems of diagnosis, prediction and planning proves the advantage of the expert system for making decisions on radiation protection. The computer system СДАЧА can provide the use of stored information and research data on the effects of the accident for creating such an expert system.

In this case the task of making desisions is characterized by the following:

- the possibility of quantitative determination of the magnitude of the acting factors;

- the necessity quickly to select the most economical (for its cost) and the most effective (for the given situation) decision out of many possible ones;

- the great number of variable quantities characterizing the situation;

- the lack or low credibility of some original data.

These characteristics substantiate the use of the expert system primarily for the practical purposes of public health at the following levels of administrative division: raion (district), oblast' (region) and at higher levels and also in regions near Plant but in this case with account of the local conditions.

The model of the expert system ПРИОРРА (in Russian) (Making Optimum Decisions in Radiation Accident) is being created by the following scheme:

1) accumulation of facts;

2) set of production rules (i.e. expertise rules);

3) mechanism of a logical conclusion together with the structure of knowledge;

4) mechanism of making the conclusion on the base of uncertain and incomplete origional data;

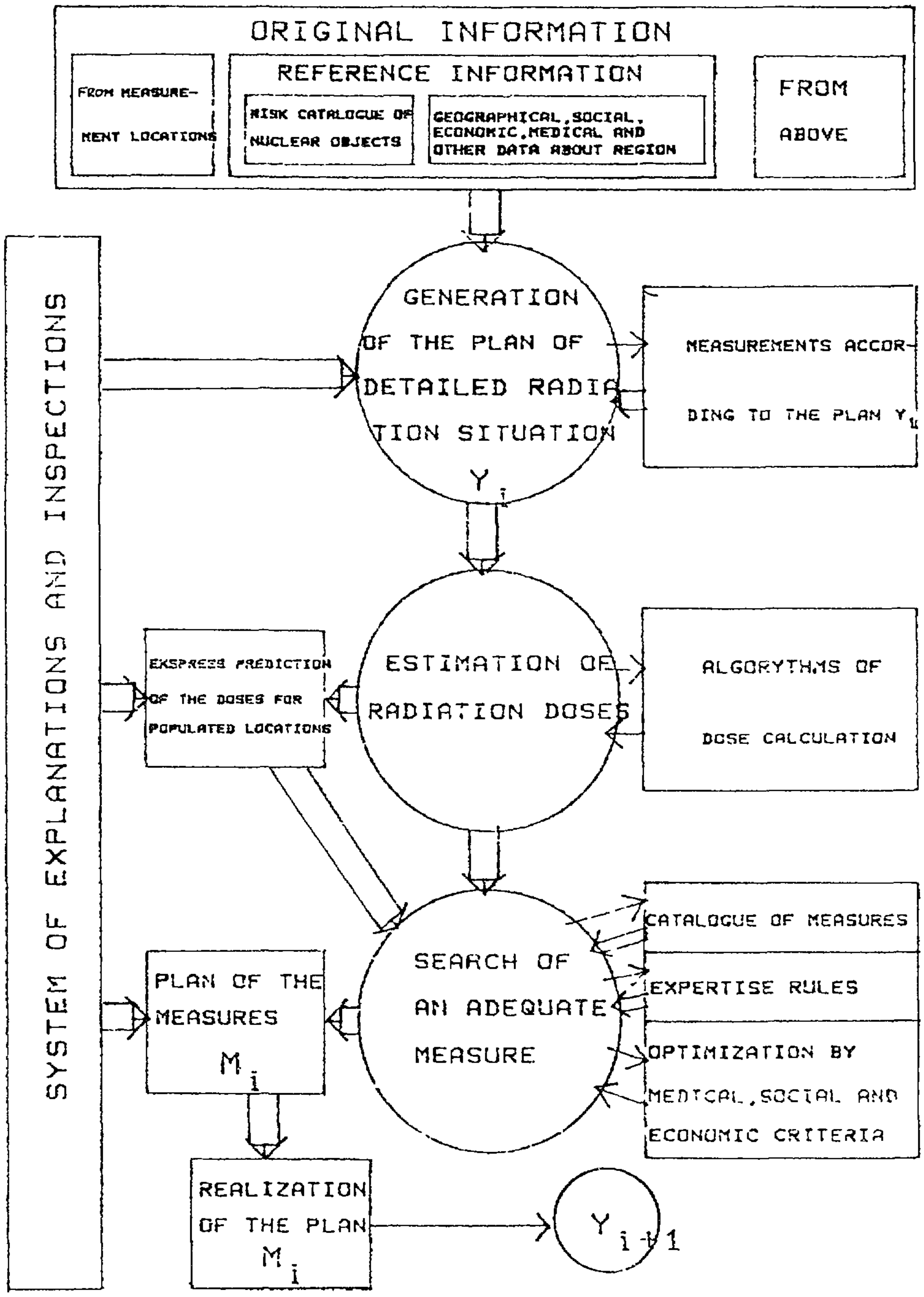
5) mechanism of explanation and inspection of each conclusion made by the system.

Analytical abilities of the system are provided by encoding expert knowledge as a set of production rules in the form:

ЕСЛИ (premises), ТО (action), (ПО), where ПО - index of determination which can be calculated by one of the adequate methods e.g. credibility coefficients, conditions of probability, etc.

The work of the expert system is carried out in accordance with the following unit-scheme (Fig. 3) where oblast' is used as a region.

The expert system is supposed to perform a constant generation of the plan of actions providing greater accuracy in estimating a radiation and hygienic situation.



1. Original information
2. Reference information
3. From measurement locations
4. Risk catalogue of nuclear objects
5. Geographical, social, economic, medical and other data about the region
6. From above

Fig. 3. Scheme of the work of the expert system ПРИОРРА

Fig. 3 (cont.)

7. Generation of the plan of detailed radiation situation
8. Measurements according of the plan Y_1
9. Express prediction of the doses for populated locations
10. Estimation of radiation doses
11. Algorythms of dose calculation
12. Plan of the measures M_1
13. Search of an adequate measure
14. Catalogue of measures
15. Expertise rules
16. Optimization by medical, social and economic criteria
17. Realization of the plan M_1
18. System of explanations and inspections

When the amount of accumulated data is sufficient for making decisions generation of the plan of actions is performed. At the next iterations it is corrected with the account of newly coming information about the radiation situation and plan realization. The unit of plan generation includes, in particular input of information on the levels of gamma radiation, concentration and density of contamination by radionuclides of soil, water, vegetation and food.

The unit of radiation dose estimation provides the calculation of average (for populated locations) and maximum individual doses of external gamma irradiation of the whole body, internal irradiation of the whole body and the thyroid by inhalation and ingestion intake of radionuclides.

The unit of the search of adequate actions is supposed to achieve the final aims: prevention of radiation disease and protection from exceeding the permissible dose values to the critical organs in the groups of increased risk. Decrease of the mean dose down to the limit of accidental irradiation and lower is desirable.

Development of criteria of the optimum selection of measures is carried out by three directions: medical, economic and social and is based on the normative document "Criteria for making decisions on protective measures against the effects of reactor accident". Generation of the plan of actions requires information on the resources in the region: drugs, transport, "clean" food and water. These data as well as information on the number of population and geography of the region must be supplied when the system is established in the region.

The unit "Explanation System" is supposed to provide the possibility of inspection of the decisions made by the system. The explanations are made by references to the points of normative and instructional documents. The experience of creating DB СДАЧА shows that the summary number of these documents does not exceed 150.

Realization of the system ПРИОРРА is carried out at Personal computers.

In conclusion the authors express their acknowledgement to the academician of the Academy of Medical Sciences of the USSR L.A. Ilyin for putting the problem constant attention and support of the work.

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PREPARATION OF AN ALL-UNION DISTRIBUTION REGISTER OF PERSONS EXPOSED TO THE EFFECTS OF RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT, WITH A VIEW TO EVALUATING EXPOSURE DOSES AND MAKING A LONG TERM PUBLIC HEaLTH FORECAST

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Abstract

The all-Union distribution register is a multilevel information and control system covering almost all parts of the country.

This register is to be kept for many decades: it is a large-scale project of great significance for the selection of strategies and tactics for the development of nuclear power, for the use of ionizing radiations in the economy, and for effective and complete solutions to radiation safety problems. Smooth and well-co-ordinated work by all specialists and organizations involved in its preparation is therefore essential.

Ministry of Public Health of the USSR has adopted a largescale program on the development of the All-Union Distributed Registry immediately after the reactor accident at Chernobyl to ensure a long-term automatized personal follow-up of accidentally irradiated individuals, their children and subsequent generations, radiation doses, health status and its changes. The All-Union Distributed Registry is an information and operative multilevel system that includes practically all the regions of the country and provides automatized support to:

- the measures on prophylactic medical examination of the population

- the necessary treatment-and-sanitation measures on dispensary system results

- the study of the structure, nature, dynamics of disease tendencies and their outcome in the followed contingent

- special and scientific programs on medical consequences of the reactor accident at Chernobyl.

Specificity of the All-Union Distributed Registry is determined not only by its large scale from the point of view of territory and quantity (more than 600.000 subjects, and a half of them,i.e. about 300 000 subjects are on the union level of the registry), by the quantity of the various specialists involved and the absence of prototype of the created system but also by the fact that it was necessary to begin the work on dispensary examination and its information supply as early as possible to evaluate medical consequences of the reactor accident and to take necessary measures. That's why the draft decisions of the All-Union Distributed Registry were being corrected according to the experience gained in the process of operation of its separate components and subsystems.

The optimal hierarchical structure of the Registry includes region, area, republic and union levels of the follow-up. This structure of the All-Union Distributed Registry makes possible maximum dynamic follow-up of the appropriate individuals, the effective use of computer technology (large, medium and personal computers) and mathematical software of different complexity, communicational binding of the examination data in magnetic tapes.

Before getting to the union level, the data on dispensary system of the detected groups of population undergo a comlex processing, i.e. official registration in the central region hospital or city hospital, the examination, magnetic tape information transfer, logical machine check of the data in the republic computation centres before sending off data array to Obninsk and the ultimate logical program check on the union level.

It should be emphasized that this control system provides for quite satisfactory quality of documents received on the union level of the Registry. The system of double control (visual one at the examination comission and a machine check in the computing centres) practically excludes the possible registration of the false documents which are not higher than 0.5 per cent.

The All-Union Diatributed Registry consists of three main objective subsystems of support:

- organization- and-medicine
- mathematical software
- dosimetry

The main functions of subsystems:

1) working out of formalized medical documents and instructions to fill them up

2) magnetic tape control, database maintenence, information processing with special computer program

3) calculation and reconstruction of individual radiation doses, separation of risk groups.

Now we discuss the structure and function of the registry subsystems mentioned above.

The first subsystems, i.e. organisation-and-medicine support includes Registry Regulations which determine the purposes, structure and executive institutions. These Regulations also control the order of information processing on different levels, the study population, as well the volume and frequency of prophylactic and treatment-and-sanitation measures. The most important aspect of the All-Union Distributed Registry function is a preparation of medical documents for computing, i.e.:

- a record card filled up once
- a medical card with the data on initial and subsequent examinations
- dosimetry data list

Organization-and-medicine support of the Registry also is composed of a number of instructions and recommendations relating to the correct registration of the documents mentioned above on the region level and information transfer to magnetic tapes. At present a large volume of the local instructional-methodical work has been done to provide the right official registration of the original documents.

The second subsystem (mathematical software) consists of three blocks: control and correction of the initial documents, database management system and an analytical block.

Logical machine check includes two complexes of software. One of them provide test and correction of all initial materials personally. The second one associates with the whole data bulk. The machine check results in an error protocol in a suitable form and a compiled magnetic tape with false documents for correction.

The second block, i.e. the All-Union Distributed Registry data-base provides information storage and multipurpose information access. The choice of DBMS for the All-Union Distributed Registry follow-up of the persons entered into the Registry and also the realization of complicated queries.

The third analytical block records output data on the All-Union Distributed Registry status and dynamics and also reveals tendencies in health status of the study groups.

The dosimetry subsystem of the registry effects the automated calculation and transfer to database the individual absorbed doses of the internal and external exposure which are accumulated in the thyroid gland and the whole body. For this, the information entering into the Registry after filling up the initial documents is used. The dosimetry subsystem exercises logical control of the dosimentry registry information besides the calculation and reconstruction of the absorbed doses.

Right before this Conference, in Obninsk was held the meeting of the leading experts of the country. They have developed concrete proposals concerning the development of regional and central informational search systems of radiation hygienic data about environmental contamination and contamination of food products. These systems, function within the Registry, will form the informational basis for individual dose reconstruction for future Registry functioning.

Creation and introduction of the Registry, provision of long-term automated personified registration of individuals subjected to the action of ionizing radiation is a complicated organizational,medical, scientific and technical task. Long-term character of the Registry functioning (several decades), its large scale, demand good organized coordinated work of every involved specialist and organization.

As an example, we can take data retrieval on the children who had thyroid dose exceeding in a number of cases 300 mSv (these children compiled about 2-3% of the retrieval). The total volume of the retrieval was about 40 000 children. For these children we had the information about the levels of thyroid hypophysial hormone. THH in blood serum. Radioimmunoassay of the serum was conducted after 6 months after radiocontamination.

The concentration of THH is in the norm (within 0,5-4,5 med/1), that shows the absence of alterations in the function of thyroid gland. Every registered child is followed according to the programme of dyspancerization.

One more example concerning one of the regions of Ukraine.

Among 65 000 of evacuated and lining on the controlled territories on the day of the accident there I007 pregnant women. Pregnancy was preserved in 97,4% of the women, 96% of them had no pathology in the course of pregnancy. 98% had timely delivery. These data show the effectiveness of the undertaken complex measures of treatment and sanitation.

For the future development of the Registry we must conduct multilevel analysis of the huge volume of collected data and provide for long-term dynamic functioning of the Registry.

ORGANIZATION AND PLANNING OF WORK INVOLVED IN THE LONG TERM CLINICAL OBSERVATION OF CHILDREN WITH A HIGH RADIATION RISK

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Abstract

Operation of the register involves analysing the basic parameters characterizing the health of children, carrying out epidemiological studies on various types of disease, refining dose parameters and reconstructing actual doses, establishing spatial and temporal dose distribution patterns, providing systematic information in support of the register, and so on.

By 16 May 1986, thyroid dose monitoring had been carried out and detailed blood analyses performed on 140 000 children, who were also given complete medical examinations by specialists. In 95% of these children, the calculated caesium intake at the end of the year following the accident was less than 1 rem.

Further information support for the register of the child population with the same comprehensive volume of medical information will make it possible to study the teratogenic effects of ionizing radiation and abnormal growth and development of children exposed at an early age, and to determine risk coefficients as a function of time, teratogenesis and cancer of the more sensitive tissues, as well as the effects of small doses of ionizing radiation.

Elaboration of prophylactic measures of social and medical nature to be taken after the accident at the Chernobyl NPP was based primarily on knowledge of quantitative and qualitative indicators, characterizing the health status of residents, taking into account the dose burden. This is of particular significance for pediatric contingent, being the most vulnerable critical group of population, and forming at the same time the foundation of future health and well-being of the nation.

Accordingly, it seems evident, how important it is to develop a specialized register for pediatric contingent, exposed to ionizing radiation following the accident at Chernobyl NPP, to be able to ensure long-term computer-aided personal registration of pediatric patients, radiation doses, state of their health and changes in the latter.

So far, no uniform concept has been accepted in our country regarding development and functioning of registers, and provision of substantiated criteria, categories, levels of observation, organized support of such computerized systems. In the literature available there are presented data on design and functioning of clinical-dosimetric registers, specifically, for residents of Hiroshima and Nagasaki who survived atomic bombing, and also for miners from uranium mines. A special feature in functioning of these registers is that they were compiled in a retrospective way and include partial clinical data obtained through sociologic polls on morbidity, mortality rate, general condition of injured persons. At the same time, keeping of such registers for a long time showed that a desire to enter maximal amount of information in a data base is hardly warranted, since it becomes impossible to process the material, to generalize it, and thus the number of errors increases in avalanch-like manner.

Therefore, at the stage of designing a specialized clinical-dosimetric register, the top-priority tasks are to develop a uniform concept of its functioning, substantiate criteria, levels, categories of observation, provision of software, and organizational support of a register.

Functioning of register envisages analyses of principal parameters, characterizing the health status of pediatric patients, epidemiologic studies, clarifying various nosologic forms, assessment of dose parameters, their reconstruction and normalization, elucidation of temperospatial distribution of doses, supply of systematic information for support of register, elaboration and correction of prophylactic measures, and, finally, working out of recommendations of social and medical character aimed at maximally possible lessening of effects of ionizing radiation.

Proceeding from the above, composing and functioning of a register for pediatric contingent included forming and collection of input information, its formalization, development of a data base, analysis and prognosis of possible disorders in health status of pediatric population due to effects of ionizing radiation, and, finally, making of decisions and their implementation (Fig. I).

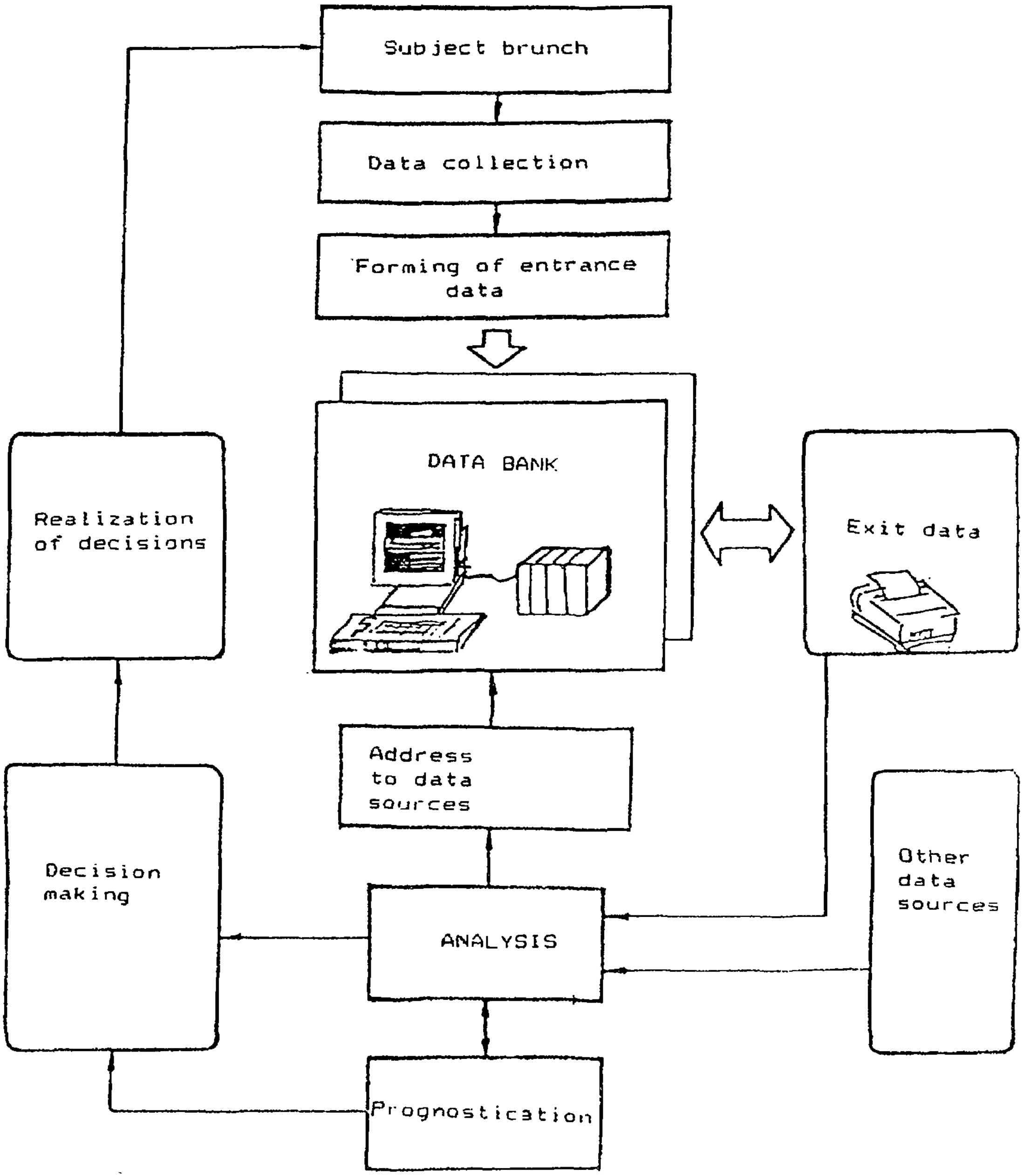


FIG. 1.

SCHEME OF ARRANGING AND FUNCTIONING OF REGISTER FOR PEDIATRIC POPULATION.

The first stage of work on the register appears essential and in many respects crucial for its successful functioning, and its adequacy to the real situation. This stage comprises the following items:

- perception, abstraction and description of application domain;
- clarifying and elucidation of users' information demands;
- design of conceptual infological model and external infological models of application domain;
- datalogical design.

In view of the above, the following tasks were set at the first stage of work:

I) to identify the groups of persons eligible for entering in the register;

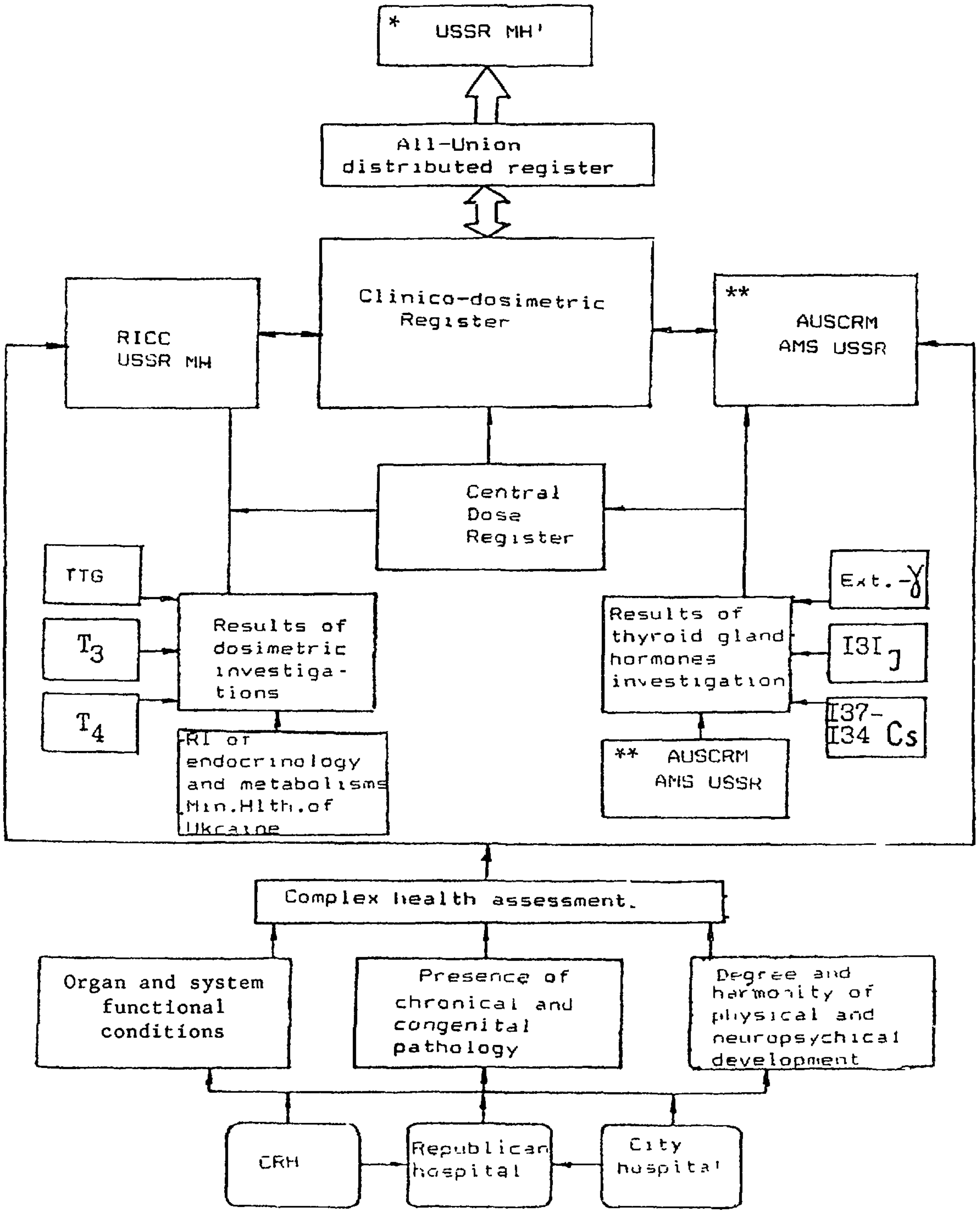
2) to define the volume and content of information, needed for composing the register;

3) to choose the way of obtaining the required information and to organize its collection;

4) to collect, formalize and enter information into computer.

The principal criterion for entering in a specialized subregister for further in-depth scientific studies of pediatric contingent with increased radiation risk were doses of thyroid exposure over 2 Gy. The information was supplied through the following scheme (Fig. 2)

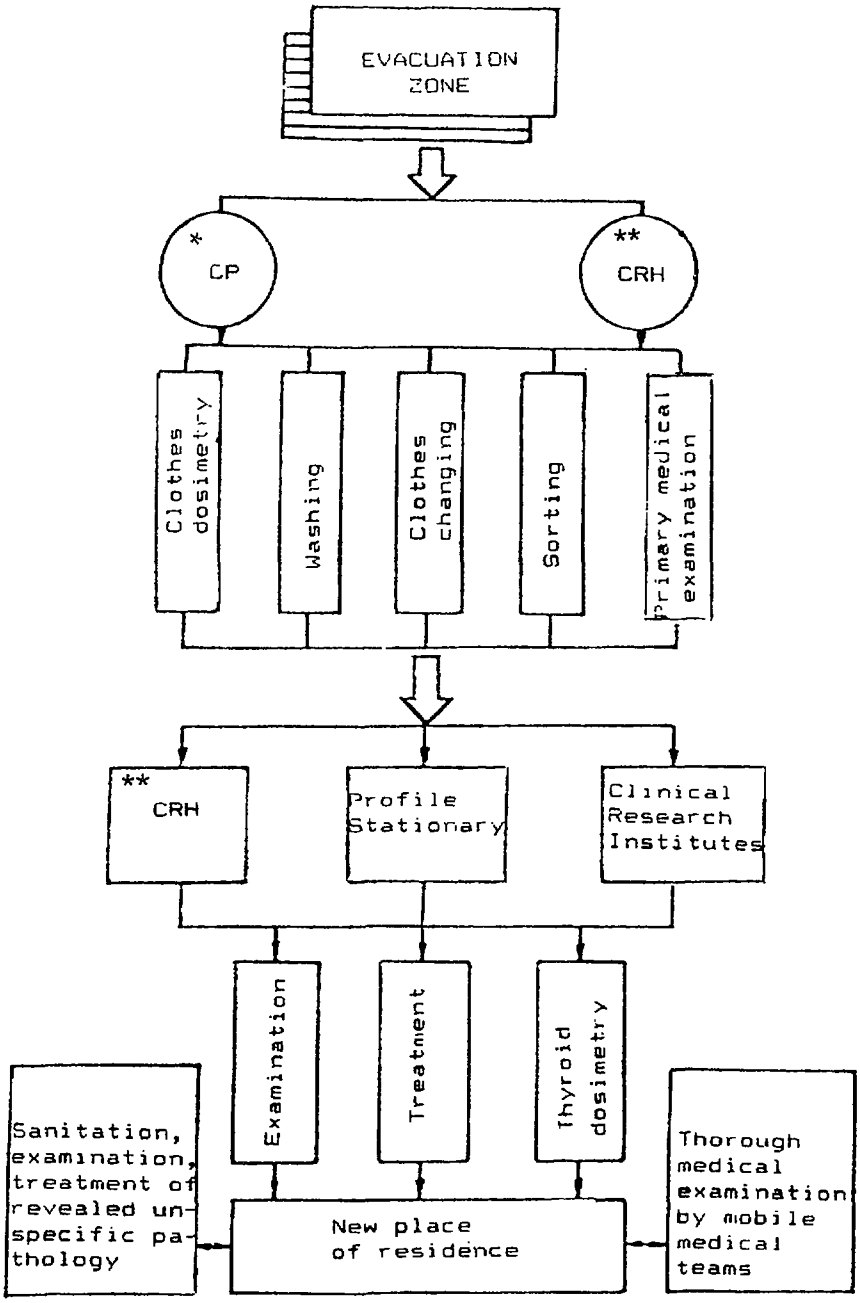
To accomplish the above-mentioned tasks the Ministry of Public Health of the UkrSSR has organized 203 republican medical teams consisting of a therapist, pediatrician, obstetrician-gynecologist, laboratory assistant, dosimetrist. The work performed allowed determining of groups to be included in prophylactic observation depending on thyroid dose of iodine radionuclides.



* USSR Ministry of Health
** All-Union Scientific Centre of Radiation Medicine

FIG. 2.

SCHEME OF INFORMATION STRUCTURE IN COMPILING REGISTER FOR PEDIATRIC CONTINGENT WITH INCREASED RADIATION RISK.



*   Control post
** Central Regional Hospital

FIG. 3.

SCHEME OF ORGANIZATION OF MEDICAL DOSIMETRIC SERVICE DURING EVACUATION OF PEDIATRIC CONTINGENT AND PREGNANT WOMEN AFTER THE CHERNOBYL ACCIDENT.

Till May I6, I986, I40 thousand infants and children underwent radiation monitoring of the thyroid gland. Parallel to this, comprehensive analysis of blood was made and pediatric contingent was examined by doctors of various specialities. Owing to devised organizational measures it became possible to start on IOth of May evacuation of pediatric population in an organized manner to southern regions of the UkrSSR where infants and children could improve their health. The stages of evacuation of pediatric contingent and pregnant women are depicted in Fig. 3.

Efficient system of prophylactic examination of pediatric contingent was organized with special reference to the value of radiation dose. At the same time there was established the Republican specialized dispensary on radiation protection of population. This dispensary has a consultation clinic and specialized laboratories with hematologic, endocrinologic, neurologic, and differential diagnostic units. Further, mobile human radiation counters (HRC) were made available.

To determine cesium intracorporeal content, the study enrolled primarily residents of Polessky and Ivankov districts of Kiev region, Narodichi district of Zhitomir region, and persons evacuated from the city of Pripyat and Chernobyl district.

In 95 % of children and infants the calculated dose of cesium intracorporeal content was found to be less than I rem from the moment of accident till the end of the year.

On the IOth of October there was initiated the second stage of prophylactic examination of pediatric contingents from northern districts of Kiev, Zhitomir, Chernigov regions and those evacuated from the city of Pripyat.

This examination was carried out by mobile medical teams consisting of a pediatrician, endocrinologist, hematologist, laboratory assistant, neuropathologist ophthalmologist. The patients were checked for blood thyroxin content, and also blood comprehensive analysis was made. If any somatic pathology was detected, the pediatric patients were hospitalized in corresponding units of regional hospitals. Infants younger than a year were admitted to the Kiev Research Institute of Pediatrics, Obstetrics and Gynecology, or, depending on the dose burden, to the Republican specialized dispensary on radiation protection, and Kiev Research Institute of Endocrinology and Metabolism,

To these teams local bodies of the public health system have recruited paramedical personnel including manipulation nurses. The teams were equipped with laboratory instruments and had transport facilities.

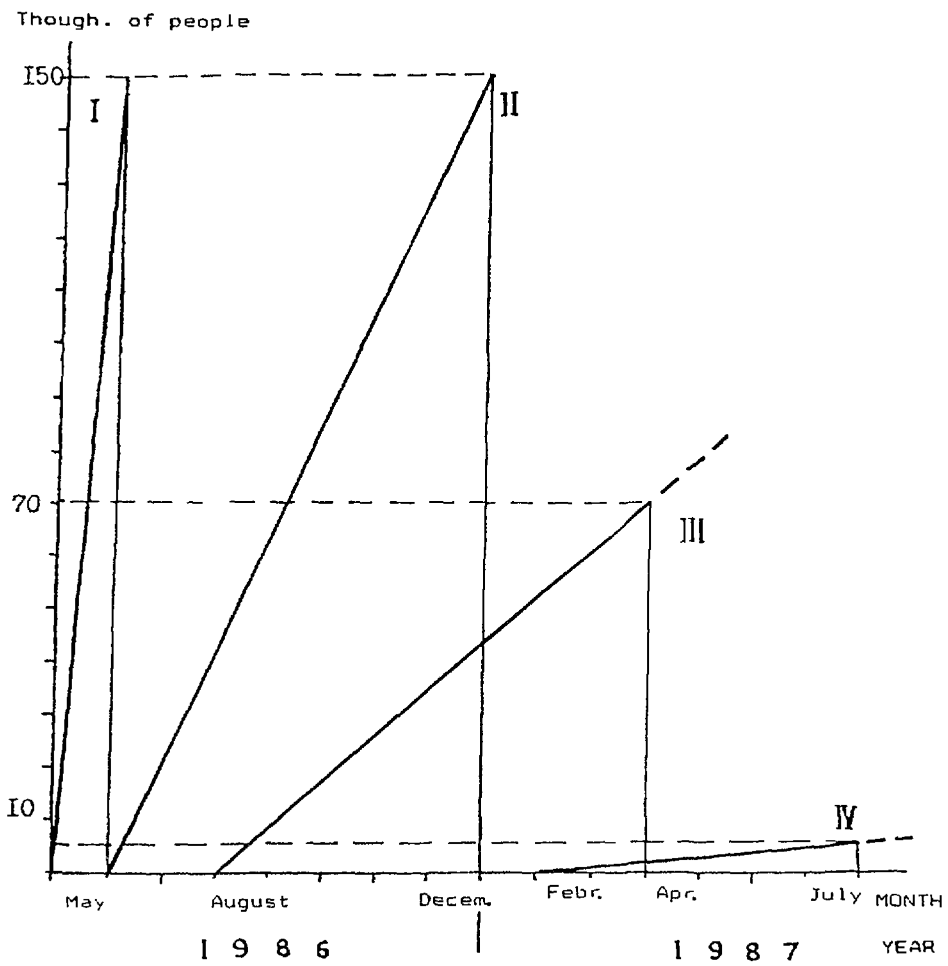
Blood smears were analyzed on the spot, while to check the blood for TTH, T_3, T_4 content, the ampules every day were delivered to Kiev RI of Endocrinology and Metabolism.

The medical teams were instructed at the Ministry of Public Health of the UkrSSR by the head of board for treatment-and-prophylactic maternal and pediatric assistance and by the head of department of specialized aid. 86 thousand of pediatric patients were examined by 60 medical teams within 2.5 months.

The obligatory condition in the work of medical teams was to fill in a specially devised information paper medium, a form of child development history, where diagnoses of all specialists were recorded, and if the necessity arose, recommendations were given regarding further follow-up and treatment of pediatric patients.

In the All-Union Scientific Center of Radiation Medicine (AUSCRM), AMS, USSR, all the forms were thoroughly analyzed and the expert opinion was expressed whether or not they were filled in correctly, and the pathology disclosed was related to data of radiation monitoring.

From the entire array of registered medical information, obtained for 86 thous. pediatric patients in the course of organized by Ministry of Public Health large-scale prophylactic examination of infants and children in the northern regions of the UkrSSR, researchers from USSCRM have selected file of documents for 5800 pediatric patients whose thyroid radiation doses exceeded 2.0 Gy (Fig. 4).



I - Stage of instrumental data collection
II - Machine processing of data, dose estimation
III- Collection of registration - medical documentation
IV - Organization of special subregister of children of excessive radiation risk group

FIG. 4.

DYNAMICS OF FORMING OF SPECIAL SUBREGISTER FOR PEDIATRIC POPULATION OF THE UKRAINIAN SSR / $D_J >$ 200 Rem /.

Formalized input information on magnetic medium provided the possibility to compose a data base which served as a basis for specialized register for pediatric contingent being under observation, and also to derive first results reflecting the state of pediatric health.

Comprehensive assessment of pediatric health included the following indices:

- functional state of organs and systems;

- degree of physical and neuro-physic development and its harmonious character;

- presence of chronic pathology (including congenital one).

By the state of their health all infants and children were assigned to the following health groups:

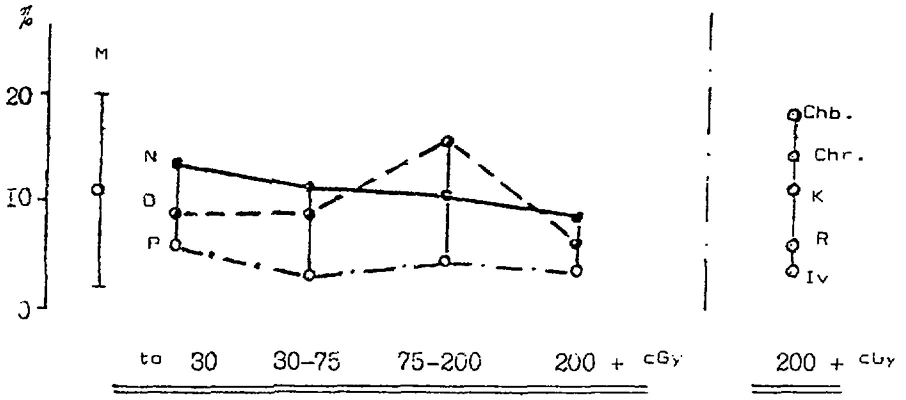
I group - healthy pediatric contingent, without any signs of disorders in the health status and who have not fallen ill during the observation period.

II group - infants and children with functional disturbances, who are at risk of developing a chronic pathology and show higher disease incidence;

III, IV, V groups - diseased infants and children with chronic pathology at the stage of compensation, subcompensation and decompensation.

During the analysis the attention was given to distribution of pediatric patients by health groups, relationship between number of pediatric patients with revealed nosologic forms and conditions, which may be associated with risk factors (primarily, such factors as thyroid hyperplasia) and the total number of infants and children examined. Further analysis elucidated percentage of individual, most frequently occurring diagnoses, in total structure of morbidity. These data were related to thyroid radiation dose, taking also into account the patient's place of residence.

Assessment of health status of pediatric patients with increased dose-related risk revealed, that percentage of infants and children assigned to 3d and 4th health groups was low in different dose groups and amounted to 4-8 % in Narodichi, Ovruch, Polessky, Ivankov, Kozelets, Repkin districts and to I3-I7,5 % in Chernigov and Chernobyl districts. No patients from the 5th health group were identified in the contingent examined (Fig. 5).



N - Narodichsky district
O - Ovruchsky district
P - Polessky district
Chb - Chernobylsky district
Iv - Ivankovsky district
Chr - Chernigovsky district
R - Repkinsky district
K - Kozeletsky district
M - average for Ukraine in 1980 - 1985

FIG. 5.

INCIDENCE OF CASES RELATED TO 3 - 5 HEALTH GROUPS AMONG PEDIATRIC PATIENTS WITH VARYING DOSES OF THYROID RADIOIODINE IRRADIATION (%)

Presence of chronic or primary detected diseases and premorbid conditions was not influenced by belonging to a dose group. Only territorial differences were disclosed. For the period of examination the number of pediatric patients with determined diagnoses was the lowest in Ovruch district of Zhitomir region (24,5 %) and the highest one was in Chernobyl district of Kiev region (52 %).

In order to analyze the structure of morbidity for all pediatric patients included in the specialized register, first, the incidence of each of determined diagnoses has been appraised. These findings revealed 5 most frequently occurring diagnoses of premorbid conditions, the percentage of which was on average 65 % from the entire number of ascertained nosologic forms of pathological and premorbid conditions: thyroid hyperplasia, chronic diseases of tonsils and adenoids, acute and chronic infections of upper respiratory tract, iron deficiency anemia, diseases of teeth and their supporting apparatus.

Some territorial special features have been disclosed in the incidence of thyroid hyperplasia with respect to the total number of determined diagnoses in each group. In fact, the proportion of thyroid hyperplasia (TH) in the structure of morbidity of pediatric patients with increased radiation risk in Zhitomir region equalled 34,2 %, in Ovruch district, and 36,8 % in Narodichi district. These values differed substantially in various districts of Kiev region: in Chernobyl district the TH proportion was I6,4 %, in Ivankov district it amounted to 28,0 %, and in Polessky district it reached 60,3 %. No clear-cut differences in the TH proportion were found in surveyed districts of Chernigov region, where it amounted to 45,9 - 74 % from the total number of all diagnoses.

In addition, the analysis of age-related distribution of the TH demonstrated successive increase in TH incidence with advancing age. For instance, the incidence of detected TH in pediatric contingent from Narodichi district in the age groups under 3 years, 3-6 years, and 7-I4 years varied from I5.6 to I7.6 and 27.8 %; in pediatric patients from Ovruch district it ranged from 5.7 to II.4 and I4.3 %, while for Chernigov district it was from I2.6 to 27.8 and 38 %.

The TH incidence may be regarded as an evidence for iodine deficiency in the given region (Fig. 6). From this viewpoint the situation is the most favourable in Narodichi and Ovruch districts of Zhitomir region. In these districts, in the course of prophylactic examination mean TH incidence in pediatric patients with increased risk was found to be I5.5 %. In Chernigov region this value amounted on average to 28.6 % in pediatric contingent with increased radiation risk. In Kiev region the TH incidence varied considerably in different districts: in Chernobyl and Ivankov districts this pathologic condition was identified in I0.2 of pediatric contingent, and in Polessye this value reached 33.4 %.

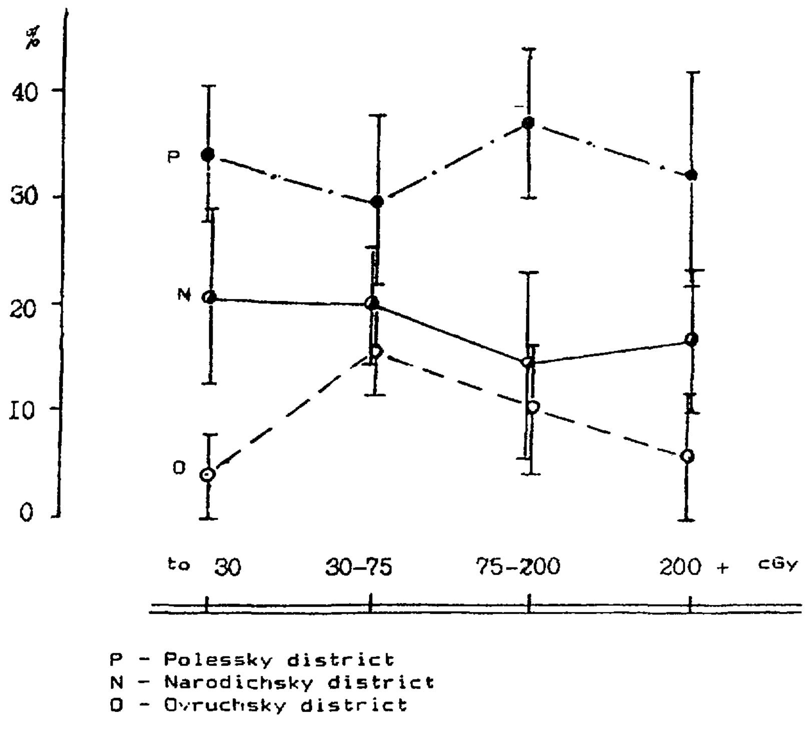


FIG. 6.

INCIDENCE OF THYROID HYPERPLASIA IN PEDIATRIC PATIENTS WITH VARYING DOSES OF THYROID RADIOIODINE IRRADIATION (%)

Therefore, primary analysis of input information of a specialized subregister for pediatric contingent with increased radiation risk revealed peculiarities in the health status of infants and children in the surveyed districts of Kiev, Chernigov and Zhitomir regions, and also disclosed the incidence of the most frequently occurring diseases. These findings will form the basis for further long-term dynamic follow-up of pediatric patients exposed to ionizing radiation, and will provide the possibility to elaborate measures aimed at minimizing the consequences of radiation effects.

Further information support of the pediatric register provided under the same conditions of expanded volume of medical information will allow the researchers to clarify the following scientific issues:

- teratogenic effects of ionizing radiation, particularly cases of mental retardation, delayed development and growth;

- developmental and growth anomalies in pediatric patients exposed to radiation at early age;

- ascertainment of risk coefficients, depending on time, teratogenesis, cancer of the most sensitive tissues, elucidation of effects of low doses of ionizing radiation.

And, finally, it became possible to tackle the problem of standardizing the values discussed proceeding from the extent of harm caused to human health.

DISCUSSION

S.P. YARMONENKO (USSR)

The sad experience of the Chernobyl accident has revealed shortcomings in knowledge of physicians about biological effects of ionizing radiation. That results in certain difficulties in involvement of these physicians to the works on the accident consequences liquidation as well as in the fact that this lack of special education of medical personnel is one of the main reasons of radiophobia among general public.

My proposition is to introduce into the Resulting Document of the Conference the following point:

to improve the education of the contemporary physicians in the field of radiation medicine. For this purpose to introduce the course of this discipline for medical students.

STATEMENT BY PARTICIPANTS

The human mind has discovered unprecedented possibilities in the sphere of use of nuclear energy for peaceful purposes. Today, everything depends on what nuclear energy will be used for -- either the creation and development of mankind's creative potential, or its destruction.

We, participants in the Conference, resolutely come out in support of creation -- the peaceful coexistence of all states and the common use of the enormous energy of the atom for the development of science, engineering and prosperity of all peoples. The destructive force of the military atom must never be let out of control, for otherwise there will be a global catastrophe for all life on Earth.

The Chernobyl accident has once again confirmed the necessity of the governments of all countries to take measures which would rule out any mischances in the use of nuclear energy. We welcome any steps which may be taken in this direction.

Having thoroughly discussed the medical consequences of the accident at the Chernobyl Nuclear Power Station, we believe that today the duty of each state and each citizen is to become aware of their historical responsibility for reducing nuclear armaments.

We are convinced that the new thinking and new realistic principles of interstate relations, based thereon, will eventually place the energy of the atom entirely at the service of mankind. The Soviet-American Treaty on the Elimination of Medium- and Shorter-Range Missiles, signed by Mikhail Gorbachev and Ronald Reagan, provides a groundwork for our optimism.

All of us, our patients, children and grandchildren need a world without missiles and nuclear weapons.

Join in the chorus of physicians and medical scientists!

CONCLUDING SPEECH

A.E. ROMANENKO

Esteemed participants of the Conference!

Dear guests!

Ladies and gentlemen!

Comrades!

Here, in the capital of the Soviet Ukraine, we have held a major scientific conference concerned with medical aspects of the accident at the Chernobyl Nuclear Power Station, which, judging by the keen attention shown in it by specialists and broad sections of the public, has acquired global significance.

Despite the fact that two years have already passed since the accident, the interests taken in everything that is connected with Chernobyl does not diminish. This is evidenced by the accreditation at the Conference of almost 140 newsmen, including over 30 foreign journalists, who represent 26 Soviet and 23 foreign mass media.

The Conference was attended by specialists from 26 ministries and departments of the USSR and Union republics, 45 research establishments, as well as more than 60 foreign scientists, representatives of the IAEA and a number of international organizations.

It is no mere chance that such a great interest is displayed in the accident at the Chernobyl NPS: its scale, despite the preceding experience in other countries, proved unexpected, thus posing before the country's public health services extremely difficult problems and tasks of the protection of health of people in the areas involved in that situation. These problems and tasks called for scientific comprehension, quick response and timely decisions.

The accident at the Chernobyl NPS had a number of distinctive features which prevented making full use of the results of numerous theoretical and applied studies previously carried out both in this country and in foreign and international organizations, which dealt with problems of radiation safety. On the other hand, as shown by the experience of Chernobyl, the complexity and manysidedness of the problems of population protection in the case of radiation accidents, which know no state boundaries, call for large-scale international cooperation.

The two years that have passed were remarkable not just for the strenuous work aimed at neutralizing the accident and eliminating its immediate consequences, but also for the urge to undertake further exploration of the problems of coexistence of mankind and the peaceful atom. Amidst all these problems, prominence has been given to researches in the field of radiological medicine -- a rapidly developing branch of medical science, vital to which are the cooperation of various branches and involvement of many countries.

Twenty-nine reports have been made at the Conference. Running all through the reports was this: for the first time in world practice, large-scale state-organized measures have been implemented, basically new decisions have been made, and the entire medical experience has been tapped to maintain the health of those who took part in the elimination of the accident's aftermath, as well as the residents of the accident-stricken areas.

The participants and guests of the Conference had an opportunity to visit the Chernobyl Nuclear Power Station, the town of Slavutich built for its personnel, to familiarize themselves with the work of the All-Union Center of Radiation Medicine under the USSR Academy of Medical Sciences and a number of research and medical-and-prophylactic establishments directly involved in tackling medical problems stemming from the Chernobyl accident, as well as some other medical-and-prophylactic establishments in Kiev.

Allow me to extend my sincere gratitude to all our guests, representatives of international organizations, such as the United Nations Scientific Committee for Atomic Radiation Effects, the World Health Organization, and the International Atomic Energy Agency, who participated in the Conference.

The invitation to the Conference of the world's leading scientists and specialists enabled us to launch a wide discussion of the data obtained, and to map out ways and prospects of further studies. Generalization and utilization of the experience gained during the elimination of the aftermath of the accident at the Chernobyl Nuclear Power Station, as well as other radiation accidents, will facilitate the protection and maintenance of people's health in the context of ongoing development of nuclear power engineering.

It is with the feeling of great satisfaction that we can state: the Conference has been held in the atmosphere of mutual understanding and cooperation. This has been a meeting of colleagues united by the vital importance of the tasks we are faced with, highly humane aims and the responsibility before mankind.

Today, many in the West argue that Russians proved to be unprepared for such an accident. However, as testified by the entire work of the Conference, this was not the case. The questions of organization and effectiveness of the measures that were taken were based on medical approaches which had been worked out in advance and their proper organization. In my opinion, this is the most important thing that can be inferred from the Kiev meeting, for it undertook a thorough scientific analysis of the Soviet public health system.

Along with this, as was with good reason pointed out in the debates, the elimination of the accident's aftermath revealed serious shortcomings. In particular, there was lack of a comprehensive system approach to the elimination of a large-scale radiation accident, physicians showed inadequate practical knowledge in the field of radiation pathology, while the radiological service was short of dosimeters and radiometers. A considerable part of equipment proved to be outdated and obsolescent. The sanitary-and-educational and explanatory work among the population was obviously inefficient.

At the same time, it should be noted once again that the Conference has convincingly proved: our experience of a truly titanic and effective effort to eliminate the consequences of the accident at the Chernobyl Nuclear Power Station is of great importance not only for Soviet but also world science and practice. This experience is invaluable for further development of nuclear engineering and prevention of nuclear war.

Allow me once again to thank all the participants and guests of the Conference, as well as those who delivered reports and spoke in the debates. I wish you all good health and every success in your work. I hereby declare the Conference closed.

In a few minutes, a press conference for Soviet and foreign newsmen will be held in this hall.

ORGANIZING COMMITTEE

Chairman SERGEEV Gennady Vasilievich	First Deputy Minister of Public Health of the USSR
Vice-Chairman KONDRUSEV Alexander Ivanovich	Deputy Minister of Public Health of the USSR
Vice-Chairman ROMANENKO Anatoly Efimovich	Minister of Public Health of the Ukrainian SSR; Director of the All-Union Scientific Centre of Radiation Medicine, USSR Academy of Medical Sciences
Vice-Chairman ILYIN Leonid Andreevich	Director of Institute of Biophysics, USSR Academy of Medical Sciences, Vice-Chairman of USSR Academy of Medical Sciences

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