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ONE DECADE AFTER CHERNOBYL

Summing up the Consequences of the Accident

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Vienna, 8–12 April 1996

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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ONE DECADE AFTER CHERNOBYL

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AND HELD IN VIENNA, AUSTRIA, 8-12 APRIL 1996

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VIENNA, 1996

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FOREWORD

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

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

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

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

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

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

The Proceedings contain a summary of the Conference results and the texts of oral presentations and discussions at the Conference, while an IAEA technical document (TECDOC) will reproduce the material from 181 poster presentations as well as the List of Participants.

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

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SUMMARY OF THE CONFERENCE RESULTS

Chairperson

A. MERKEL
Germany

SUMMARY OF THE CONFERENCE RESULTS

This summary was formulated on the basis of the following: updating reports and keynote presentations; Background Papers prepared by expert panels, and discussions of these by the Conference; and the Session Chairpersons' conclusions, which also took into account material submitted in posters and in technical exhibitions. It does not necessarily reflect the views of governments of member countries of the sponsoring organizations.

The Joint Secretariat of the Conference recommends *that this Summary of the Conference Results be used as the basis for decisions concerning future work and collaboration with the aim of alleviating the consequences of the Chernobyl accident.*

1. On 26 April 1986, the most serious accident in the history of the nuclear industry occurred at Unit 4 of the Chernobyl nuclear power plant in the former Ukrainian Republic of the Union of Soviet Socialist Republics, near the present borders of Belarus, the Russian Federation and Ukraine. The reactor was destroyed and, over the ensuing 10 days or so, large amounts of radioactive material were released to the environment.

INITIAL RESPONSE

2. Emergency measures had to be taken to bring the release of radioactive material under control, to deal with the debris from the reactor, and subsequently to construct a confinement structure, the so-called 'sarcophagus', which was completed in November 1986, to contain the remains of the reactor core.

3. The response to the accident was carried out by a large number of ad hoc workers, including operators of the plant, emergency volunteers such as firefighters, and military personnel, as well as many non-professional personnel. All these people became known by the Russian term *likvidator*. About 200 000 'liquidators' worked in the region of Chernobyl during the period 1986–1987, when radiation exposures were highest. They were among some 600 000 to 800 000 persons who were registered as involved in activities relating to alleviating the consequences of the accident. This includes persons who participated in the cleanup after the accident (including cleaning up around the reactor, construction of the sarcophagus, decontamination, road building, and destruction and burial of contaminated buildings, forests and equipment), as well as many other general personnel who worked in the territories designated as 'contaminated' and who generally received low doses.

4. Over the period from 27 April to mid-August 1986, about 116 000 members of the public were evacuated from their homes in the region around the Chernobyl plant, the intention being to protect them against radiation exposure. A so-called 'exclusion zone' was established, which included territories with the highest dose rates, to which public access was prohibited. This exclusion was continued in the independent successor countries of Belarus and Ukraine after the dissolution of the Soviet Union. The exclusion zone covers in total 4300 km^2.

RELEASES[1]

5. The total activity of all the radioactive material released in the accident is today estimated to have been around 12×10^{18} Bq, including some $(6–7) \times 10^{18}$ Bq due to noble gases. About 3–4% of the used fuel in the reactor at the time of the accident as well as up to 100% of noble gases and 20–60% of the volatile radionuclides were released. This current estimate of activity of the material released is higher than the estimate of activity reported in 1986 by the authorities of the former USSR, which was made on the basis of summing the activity of the material deposited within the countries of the former USSR. However, this reassessment of the source term does not alter the estimations of individual doses.

6. The radionuclide composition of the material released in the accident was complex. The radioactive isotopes of iodine and caesium are of the greatest radiological significance: the iodines, with their short radioactive half-lives, had the greater radiological impact in the short term; the caesiums, with half-lives of the order of tens of years, have the greater radiological impact in the long term. The estimates for the activity of the amounts of the key radionuclides released are as follows: ^{131}I: $\sim(1.3–1.8) \times 10^{18}$ Bq; ^{134}Cs: $\sim 0.05 \times 10^{18}$ Bq; ^{137}Cs: $\sim 0.09 \times 10^{18}$ Bq. These values correspond to about 50–60% of the ^{131}I in the reactor core at the time of the accident and about 20–40% of the two radiocaesiums.

DEPOSITION

7. Material released to the atmosphere was widely dispersed and eventually deposited onto the surface of the Earth. It was measurable over practically the entire northern hemisphere. Most of the material was deposited in the region around the plant site, with wide variations in deposition density. The areas of the surrounding

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[1] The amount of a given radionuclide is expressed in terms of the quantity 'activity', which corresponds to the number of spontaneous nuclear transformations releasing radiation per unit time. Its unit is the reciprocal second (s^{-1}), termed becquerel (Bq).

territories of Belarus, Russia and Ukraine in which activity levels of ^{137}Cs in excess of 185 kBq/m^2 were measured were estimated at 16 500 km^2, 4600 km^2 and 8100 km^2 respectively.

RADIATION DOSES

8. The 200 000 persons who participated in 1986–1987 in the 'liquidation' of the consequences of the accident received average doses of the order of 100 mSv.[2] Around 10% of them received doses of the order of 250 mSv; a few per cent received doses greater than 500 mSv; while perhaps several tens of the people who responded initially to the accident received potentially lethal doses of a few thousands of millisieverts.

9. The 116 000 people who were evacuated from the exclusion zone in 1986 had already been exposed to radiation. Fewer than 10% had received doses of more than 50 mSv and fewer than 5% had received doses of more than 100 mSv.

10. The radioiodines released delivered radiation doses to the thyroid gland. Iodine was absorbed into the bloodstream, generally by ingestion in foodstuffs, mainly contaminated milk, and also by inhalation from the initial radioactive cloud, and accumulated in the thyroid gland. Doses to the thyroid were anticipated to be particularly high compared with those to other body organs, especially for children. Estimated equivalent doses to the thyroid (made primarily on the basis of measurements reported for 150 000 people in Ukraine and also in Belarus and the Russian Federation) of up to several sieverts or more[3] were made available for the Post-Accident Review Meeting on the Chernobyl Accident held in Vienna in 1986, the International Chernobyl Project (carried out in 1990 in order to determine the safety of continued living in contaminated territories), and all other international evaluations to date. However, no independent international verification of the reported absorbed thyroid dose was possible.

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[2] The quantity radiation dose is a measure of the energy absorbed from radiation by tissues per unit tissue mass, weighted by the effectiveness of the radiation type and the radiosensitivity of the various tissues in the body. Its unit is the sievert (Sv), with a subunit of millisieverts (i.e. thousandths of a sievert) (mSv). For perspective, the global annual average radiation dose due to natural background radiation is 2.4 mSv, with considerable geographical variation. Hence, over a standard lifetime of 70 years an individual accrues an average dose of 2.4 mSv $\times$ 70 $\approx$ 170 mSv due to natural background radiation.

[3] Doses to specific organs are usually expressed in grays (Gy). For the type of radiation of concern here, a dose of 1 Gy to the thyroid corresponds to a (weighted) equivalent thyroid dose of 1 Sv.

11. The long term doses to the populations in various countries of the northern hemisphere as a result of the accident, including average doses in various countries, have been assessed by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). UNSCEAR estimated that individual doses outside the former USSR as a result of the accident were as follows: the highest national average first year dose was 0.8 mSv; the highest European regional average committed dose over the 70 years to 2056 was estimated to be 1.2 mSv. In the International Chernobyl Project, it was estimated that the highest committed doses for the 70 years from 1986 to 2056 for people living in the most contaminated territories were of the order of 160 mSv. Recent, more detailed, studies have produced similar results. For the period from 1996 to 2056, committed doses to the population living in areas with a contamination density of 185–555 kBq/m^2 will typically be of the order of 5–20 mSv; for the population living in areas with a contamination density of 555–1480 kBq/m^2, doses over this period will be of the order of 20–50 mSv, mainly from external exposure. However, in localities where there are particularly high transfer coefficients from soil into foodstuffs, the internal exposure alone to the population could exceed 50 mSv over the 70 years.

CLINICALLY OBSERVED EFFECTS

12. A total of 237 occupationally exposed individuals were suggested to be suffering from clinical syndromes attributable to radiation exposure and were admitted to hospital. Acute radiation syndrome (ARS) was diagnosed in 134 cases. Of these 134 patients, 28 died as a consequence of radiation injuries, all within the first three months. Two more persons had died at Unit 4 from injuries unrelated to radiation (and one additional death was thought to have been due to a coronary thrombosis). Gastrointestinal damage was a serious concern, causing early and lethal changes in intestinal function among 11 patients who had received doses greater than 10 Gy. The deaths of 26 of the 28 patients who died were associated with skin lesions that affected over 50% of the total body surface area. After the acute phase, 14 additional patients have died over the past ten years; however, their deaths do not correlate with the original severity of ARS and are therefore not necessarily — and in some cases are certainly not — directly attributable to radiation exposure.

13. There is little doubt that the patients received the best possible treatment in line with the state of knowledge at the time, in the most experienced centre available. However, the therapy of bone marrow transplantation recommended at the time was of little benefit. With today's knowledge, this is readily understandable in view of the inherent immunological risks of the procedure, the heterogeneous exposure characteristics and the other complicating injuries due to radiation, such as unmanageable gastrointestinal damage or skin lesions. Bone marrow damage can best be managed in future by the prompt administration of haemopoietic growth

factors. The most optimal combination and dose scheduling for these still need to be determined, however. For other radiation damage also, new diagnostic tools have become available which may contribute to a more accurate prognosis and more individually tailored treatment.

14. At present, the more severely affected patients suffer from multiple ailments, including effects of mental stress, and are in need of up to date treatment and preventive measures against secondary effects. Health care should be ensured for these patients, and their state of health should be monitored over the forthcoming two to three decades. Among the disease patterns encountered, it will be important to distinguish between those that are attributable to radiation exposure and those due to confounding factors intrinsic to the populations affected by the accident.

THYROID EFFECTS

15. A highly significant increase in the incidence of thyroid cancer among those persons in the affected areas who were children in 1986 is the only clear evidence to date of a public health impact of radiation exposure as a result of the Chernobyl accident. (In 1991, the report on the International Chernobyl Project had stated that "it is expected that there will be a radiogenic excess of thyroid cancer cases in the decades to come. This risk relates to thyroid doses received in the first months after the accident..."[4].) This increase in incidence has been observed in Belarus and to a lesser extent in Ukraine and in the Russian Federation. The number of reported cases up to the end of 1995 is about 800 in children under 15 years old at the time of diagnosis; more than 400 of these cases were in Belarus. In most cases the diagnoses have been confirmed by international experts.

16. The increase has been observed in children who were born before or within six months of the accident; the incidence of thyroid cancer in children born more than six months after the accident drops dramatically to the low levels expected in unexposed populations. Moreover, most of the cases of thyroid cancer are concentrated in areas thought to have been contaminated by radioiodines as a result of the accident. Thus, both temporal and geographical distributions clearly indicate a relationship of the increase in incidence to radiation exposure due to the Chernobyl accident. Furthermore, since the thyroid gland concentrates iodine, one or more radioactive isotopes of iodine are presumed to be the causative agents of the increase in incidence of thyroid cancer in children.

[4] INTERNATIONAL ADVISORY COMMITTEE, The International Chernobyl Project: Technical Report, Assessment of Radiological Consequences and Evaluation of Protective Measures, Part F: Health Impact, Section 3.11.3, p. 389.

17. At presentation, the majority of thyroid tumours were in an advanced stage, showing extension to tissues outside the thyroid gland and/or lymph node metastases and, less frequently, distant metastases. This finding is strong evidence that the observed increase could only to a small degree be attributed to increased ascertainment due to screening.

18. The pathology of virtually all the thyroid cancer cases shows papillary carcinomas, many with an unusual solid/follicular pattern of growth. The type of molecular alterations so far studied has not shown any major differences from tumours of the same type in thyroids not exposed to radiation. However, these alterations are more frequent in tumours of thyroids exposed to radiation.

19. Analyses by age at exposure confirmed the hypothesis that very young children were at the greatest risk. It is now considered that the increase in the incidence of thyroid cancer in those exposed as young children may persist. This could increase the prevalence of thyroid cancer in the affected group in the future, requiring adequate resources for dealing with it.

20. In the present case, the minimum latency period between exposure and diagnosis of thyroid cancer seems to be about 4 years. This latency period is somewhat shorter than expected on the basis of previous experience related to acute exposure to external radiation.

21. To date, only three children in the cohort of diagnosed cases have died of thyroid cancer. These post-Chernobyl papillary thyroid cancers in children, in spite of their aggressiveness, appear to respond favourably to standard therapeutic procedures if appropriately applied; however, only short term follow-up data are available as yet. There is thus a need for complete and continuing follow-up of the affected children in order to establish the optimal therapy. Life-long administration of L-thyroxine to children is mandatory after thyroidectomy.

22. The extent of the future incidence of thyroid cancers as a result of the Chernobyl accident is very difficult to predict. There remain uncertainties in dose estimates and, although it is not certain that the present increase in the incidence will be sustained in the future, it will most probably persist for several decades. If the current high relative risk is sustained, there would be a large increase over the coming decades in the incidence of thyroid carcinoma in adults who received high radiation doses as children.

23. In the event of any future accident, recognized measures should be taken under strictly defined conditions to protect populations at risk from exposure of the thyroid to radioiodine, such as prevention of the consumption of contaminated food and

iodine prophylaxis through the distribution of pharmacological doses of stable iodine. The populations living around the Chernobyl plant have historically been subject to iodine deficiency, and remedy of this deficiency through the consumption of iodized salt in food is in any case recommended.

LONGER TERM HEALTH EFFECTS

24. Apart from the confirmed increase in the incidence of thyroid cancer in young people, there have been some reports of increases in the incidence of specific malignancies in some populations living in contaminated territories and in liquidators. These reports are not consistent, however, and the reported increases could reflect differences in the follow-up of exposed populations and increased ascertainment following the Chernobyl accident; they may require further investigation.

25. Leukaemia, a rare disease, is a major concern after radiation exposure. Few fatalities due to radiation induced leukaemia would theoretically be expected according to predictive models (based on data from the survivors of the Japanese atomic bombing and others). The total expected excess fatalities due to leukaemia would be of the order of 470 among the 7.1 million residents of 'contaminated' territories and 'strict control zones', which would be impossible to distinguish from the spontaneous incidence of about 25 000 fatalities. The total expected figure among the 200 000 liquidators (who worked in 1986–1987) would be of the order of 200 fatalities against a spontaneous number of 800 deaths due to leukaemia. According to current models, about 150 of these 200 excess leukaemia deaths among the liquidators would have been expected to have occurred in the first ten years after exposure, for which the spontaneous incidence is 40. In summary, to date, no consistent attributable increase has been detected either in the rate of leukaemia or in the incidence of any malignancies other than thyroid carcinomas.

26. Among the 7.1 million residents of 'contaminated' territories and 'strict control zones', the number of fatal cancers due to the accident is calculated, using the predictive models, to be of the order of 6600 over the next 85 years, against a spontaneous number of 870 000 deaths due to cancer. Future increases over the natural incidence of all cancers, except for thyroid cancer, or hereditary effects among the public would be difficult to discern, even with large and well designed long term epidemiological studies, as had already been stated in the report on the International Chernobyl Project.

27. Increases in the frequency of a number of non-specific detrimental health effects other than cancer among exposed populations, and particularly among liquidators, have been reported. It is difficult to interpret these findings because exposed populations undergo a much more intensive and active follow-up of their state of

health than does the general population. Any such increases, if real, might also reflect effects of stress and anxiety.

28. Existing population based cancer and mortality registries should be improved or, where appropriate, such registries should be set up. In addition, specific studies to investigate the reported increases and also the predicted increases, particularly in leukaemia among liquidators, should be carried out. This should be done using carefully designed protocols applied uniformly to analyse, and possibly to distinguish the effects of, confounding factors.

PSYCHOLOGICAL CONSEQUENCES

29. Several important studies and programmes have been conducted over the past ten years in the area of social and psychological effects of and reactions to the Chernobyl accident. These have confirmed earlier findings (including those of the International Chernobyl Project) that there are significant psychological health disorders and symptoms among the populations affected by the Chernobyl accident, such as anxiety, depression and various psychosomatic disorders attributable to mental distress. It is extremely difficult to distinguish the psychological effects of the Chernobyl accident from effects of economic hardship and the dissolution of the USSR.

30. The psychological effects of the Chernobyl accident resulted from the lack of public information, particularly immediately after the accident, the stress and trauma of relocation, the breaking of social ties, and the fear that any radiation exposure is damaging and could damage people's health and their children's health in the future. It is understandable that people who were not told the truth for several years after the accident continue to be sceptical of official statements and to believe that illnesses of all kinds that now seem more prevalent must be due to radiation. The distress caused by this misperception of radiation risks is extremely harmful to people.

31. The lack of consensus about the accident's consequences and the politicized way in which they have been dealt with has led to psychological effects among the populations that are extensive, serious and long lasting. Severe effects include feelings of helplessness and despair, leading to social withdrawal and loss of hope for the future. The effects are being prolonged by the protracted debate over radiation risks, countermeasures and general social policy, and also by the occurrence of thyroid cancers attributed to the early exposures.

32. There is an urgent need to foster trust in the personal ability to change one's life for the better; to encourage small-scale and communal projects to improve matters locally and to support organizations promoting rehabilitation of the populations concerned; to increase public knowledge of the health effects of radiation and

radiation protection; and to develop, integrate and sustain existing networks of local authorities, specialists and researchers in the social and psychological field.

ENVIRONMENTAL CONSEQUENCES

33. Concerning direct consequences for animals and plants, lethal radiation doses were reached in some radiosensitive local ecosystems, notably for coniferous trees and for some small mammals within 10 km of the reactor site, in the first few weeks after the accident. By the autumn of 1986 dose rates had fallen by a factor of 100. By 1989 the natural environment in these localities had begun to recover. No sustained severe impacts on populations or ecosystems have been observed. The possibility of long term genetic effects and their significance remains to be studied.

34. For the human populations, the significance of the environmental contamination depends on the pathways for their exposure. The main pathways are by external irradiation from radioactive material deposited on the ground and by internal irradiation due to the contamination of foodstuffs. In the first few weeks after the accident, radioiodines were the radionuclides of the greatest radiological importance. Since 1987, most of the radiation dose received has been due to ^{134}Cs and ^{137}Cs, with a minor contribution from ^{90}Sr, while ^{239}Pu has made a minimal contribution to dose.

35. Several items of the normal diet were contaminated by radioactive materials. Early after the accident, key foodstuffs such as milk and green vegetables had contamination levels in excess of what is today considered acceptable by the WHO/FAO Codex Alimentarius Commission, set as maximum permitted contamination levels for foodstuffs moving in international trade. (These levels are now globally established by the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.) There are some questions about the effectiveness of the control measures that were taken in the early stages following the accident.

36. Countermeasures are relatively inefficient in reducing external exposures but can be very efficient in reducing the uptake of radioactive material. In the long term, the appropriate application of agricultural countermeasures can effectively reduce the uptake of caesium into food. Which countermeasures are the most appropriate and their effectiveness strongly depend on local conditions such as soil type. For example, in some localities where the amount of caesium deposited on the ground was relatively small, the transfer to milk could nevertheless be high. In general, no food produced by collective farms now exceeds the WHO/FAO Codex Alimentarius levels, although some foods produced by private farmers do exceed these levels.

37. The seminatural environment, i.e. with characteristics intermediate between those of managed agricultural land and those of natural environments, may have a predominant influence on the levels of future doses to the human population. The transfer factor for radionuclides from soil to the milk of cows grazing on meadows varies by a factor of several hundred, depending on the type of soil. Some food products derived from animals that graze in seminatural pastures, forests and mountain areas and wild foods (such as game, berries and mushrooms) will continue to show levels of ^{137}Cs that exceed the Codex Alimentarius levels — in some cases greatly — over the next decades and are likely to be a major source of internal doses in the future.

38. Local dose rates due to radioactive material buried at the Chernobyl site can be considerable. Furthermore, for orderly management of the provisional depositories of radioactive residues from the accident, the potential contamination of the local groundwater in the long term should be considered.

SOCIAL, ECONOMIC, INSTITUTIONAL AND POLITICAL IMPACT

39. Between 1990 and the end of 1995, decisions were taken by the authorities to further resettle people in Ukraine (about 53 000 persons), Belarus (about 107 000 persons) and Russia (about 50 000 persons). Evacuation and resettlement has created a series of serious social problems, linked to the difficulties and hardships of adjusting to the new living conditions.

40. Demographic indicators in 'contaminated' regions have worsened: the birth rate has decreased, and the work force is migrating from 'contaminated' areas to 'uncontaminated' areas, creating shortages of labour and professional staff.

41. The control measures imposed by the authorities to limit radiation exposure in 'contaminated' territories have limited industrial and agricultural activities. Moreover, the attitude of the general population towards products from 'contaminated' areas makes it difficult for produce to be sold or exported, leading to reductions in local incomes.

42. Restrictions on people's customary activities make everyday life difficult and distressing. Major rehabilitative actions have been undertaken over the past years. However, it is necessary to provide the public with more and better information on the measures taken to limit the consequences of the accident, on present radiation levels and on radionuclide concentrations measured in foodstuffs.

43. The social and economic conditions of people living and working in contaminated territories are heavily dependent on public subsidies. If the compensation system in force were to be reconsidered, some of the funds could be redirected to new industrial and agricultural projects.

44. The consequences of the Chernobyl accident and the measures taken in response, exacerbated by the political, economic and social changes of the past years, have led to a worsening in the quality of life and of public health and to unfavourable effects on social activity. The situation was further complicated in the years after the accident by incomplete and inaccurate public information on the accident's consequences and on measures for their alleviation.

NUCLEAR SAFETY

45. The main cause of the Chernobyl accident lay in the coincidence of severe deficiencies in the design of the reactor and of the shutdown system and the violation of procedures. The lack of 'safety culture' in the responsible organizations of the Soviet Union resulted in an inability to remedy such design weaknesses, even though they had been known before the accident.

46. In addition to those features of direct relevance to the causes of the accident, the original design of plants with RBMK reactors (Soviet light water cooled graphite moderated reactors) had further deficiencies. In particular, the original design of the first generation of RBMK reactors falls short of present safety objectives. Remaining deficiencies, such as the partial containment, require further attention.

47. In accordance with a dynamic approach to safety, all nuclear power plants that do not meet an internationally acceptable level of safety need appropriate upgrading or should be shut down. In September 1991, the IAEA Conference on The Safety of Nuclear Power: Strategy for the Future, expressed a consensus that the safety standards[5] of older operating plants should be reasonably compliant with current safety objectives. Active commitment to this objective remains of prime importance for ensuring an acceptable level of safety for nuclear installations and for enhancing public confidence in nuclear energy.

48. A significant number of remedial measures to enhance nuclear safety have been taken over the past decade at existing plants with RBMK reactors: technical and organizational measures were taken immediately after the Chernobyl accident, as

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[5] The Safety of Nuclear Power: Strategy for the Future (Proc. Conf. Vienna, 2–6 September 1991), IAEA, Vienna (1992).

well as safety upgrades performed between 1987 and 1991 which essentially remedied the design deficiencies that contributed to the accident. Progress has also been achieved in areas such as plant management, training of personnel, non-destructive testing and safety analysis. As a result, a repetition of the same accident scenario seems no longer practically possible. However, the possibility of other accidents leading to substantial releases cannot be excluded.

49. Some of the concerns regarding safety might also apply to other reactors designed to earlier standards if no adequate improvements have been made. The importance of periodic safety reviews is widely recognized in this regard.

50. For all RBMK plants, there are plans for further safety improvements to remedy those design deficiencies of RBMK reactors that are not directly related to the Chernobyl accident. The implementation of these plans is lagging behind what is needed because the countries concerned lack the necessary resources.

51. Expedited implementation of what has been agreed to be necessary and has already been planned is a top priority for the national nuclear programmes as well as for international co-operation:

- necessary safety improvements must be carried out independently from consideration of early decommissioning of the plants;
- more resources must be made available for enhancing the safety of the RBMK plants that are currently operated;
- the status of national regulatory authorities and their support organizations must be strengthened.

52. Backfits similar to those for other RBMK units were also performed at the Chernobyl plant. However, safety concerns with RBMK units are not only related to the remaining generic design deficiencies, but also to the quality of equipment.

53. The decision of the Ukrainian authorities to close down the remaining units at Chernobyl is not a reason for neglecting the need for safety measures and backfits during the remaining time of operation.

THE SARCOPHAGUS

54. The sarcophagus that was constructed around the destroyed reactor presently contains about 200 tonnes of irradiated and fresh nuclear fuel, mixed with other materials in various forms, mainly as dust. The total activity of this material is estimated to be 700×10^{15} Bq of long lived radionuclides. The sarcophagus has met the objectives set for the purposes of protection over the past ten years. In the long term, however, its stability and the quality of its confinement are in doubt. A collapse

of the structure could lead to a release of radioactive dust and the exposure to radiation of the personnel employed at the site. However, even in the worst case, widespread effects (beyond 30 km away) would not be expected.

55. It has been found that the sarcophagus is currently safe from the point of view of the occurrence of a criticality. It cannot be completely excluded that there exist configurations of fuel masses inside the sarcophagus that could reach a critical state when in contact with water. However, even if such a condition were to lead to elevated radiation levels inside the sarcophagus, large off-site releases would not be expected. The possible impact of such a state on site personnel needs to be clarified.

56. Opinions differ widely about the significance of the risk of an accident in Chernobyl Unit 3 caused by a collapse of the sarcophagus. More detailed investigations of this issue are required.

57. The safety of the remaining units and the stability of the sarcophagus are not the only major issues still to be resolved at the Chernobyl site. Further concerns relate to the potential for contamination, in particular to the radioactive material buried at the site. These issues are interrelated and an integrated approach is required to resolve them. The proposed construction of a second shelter over the sarcophagus should be part of such an approach. The actions financed by the European Commission in this area have contributed to achieving an integrated approach. This approach now needs to be generalized, and the know-how of the competent organizations of the former USSR should be more effectively integrated. Research and development of an adequate design and its construction are necessary in order to ensure that the sarcophagus is ecologically safe.

58. A cost-effective procedure requires that suitable steps be taken, in accordance with the progress of studies and the financial circumstances. The first measure should be the stabilization of the existing sarcophagus. This would significantly reduce the risk of its collapse and would provide the time required for the careful planning of further measures (such as a second shelter).

PERSPECTIVE AND PROGNOSIS

59. Full rehabilitation of the exclusion zone is not currently possible owing to: the existence of 'hot spots' of contamination near residential areas; the possibility of local radioactive contamination of groundwater; the hazard associated with the possible collapse of the sarcophagus; and severe restrictions imposed on diet and lifestyle.

60. Any estimates of the total number of fatal and non-fatal cancers attributable to the accident should be interpreted with caution in view of the uncertainties associated with the assumptions on which they must be based. Such projections do, however, provide a perspective on the magnitude of the long term impact and help in identifying areas needing special attention, both now (such as the incidence of leukaemia among the liquidators and of thyroid cancer among children living in 'contaminated' areas) and in the future.

61. There is a major discrepancy between the number of thyroid cancers appearing in those who were children at the time of the accident and the predicted number of such cancers on the basis of standard thyroid dosimetry and current risk projection models. This difference may be the result of several factors unique to the accident which are not typically incorporated into standard models. It is important to clarify these issues as well as to continue the programmes for the detection of thyroid tumours.

62. The increase in the incidence of thyroid cancer will most probably persist for several decades. While it is not possible to predict with certainty on the basis of current data, the estimated number of thyroid cancers to be expected among those who were children in 1986 is of the order of a few thousand. The number of fatalities should be much lower than this, if cancer is diagnosed in the early stage and if appropriate treatment is given. These people should continue to be closely monitored throughout their lives.

63. Despite the extensive scientific and medical knowledge of radiation effects, there remain important open questions with regard to the human health effects of radiation. It is necessary to continue to support research into the biological effects of radiation.

64. Different factors, such as economic hardship, are having a marked effect on the health of the population in general, including the various groups exposed as a result of the accident. The statistics for the exposed populations are being examined in the light of the clear general increase in morbidity and mortality in the countries of the former Soviet Union so as to preclude the misinterpretation of these trends as being due to the accident.

65. The public perception of the present and future impact of the accident may have been exacerbated by the difficult socioeconomic circumstances in the USSR at the time, by the countermeasures that the authorities took to minimize the accident's impact, and by the public's impression of the risks from the continuing levels of radioactive contamination.

66. Past experience of accidents unrelated to radiation has shown that the psychological impact may persist for a long period. In fact, ten years after the Chernobyl accident, the evolution of symptoms has not ended. It can be expected that the importance of this effect will decrease with time. However, the continuing debate over radiation risks and countermeasures, combined with the fact that effects of the early exposures are now being seen (i.e. the significant rise in thyroid cancers among children), may prolong the symptoms. In evaluating the psychological impact, account should be taken of the psychological effects of the breakup of the USSR, and any forecast should take into account the economic, political and sociological circumstances of the three countries. The symptoms such as anxiety associated with mental stress may be among the major legacies of the accident.

67. In view of the low risk associated with the present radiation levels in most of the 'contaminated' areas, the benefits of future efforts to reduce doses to the public still further would be outweighed by the negative economic, social and psychological impacts. It is important to develop a strategy that takes into account both the real radiological risk and the economic, social and psychological disbenefits in order to yield the greatest net benefit in human terms. In addition, measures to mitigate the psychological impact should be considered.

OPENING SESSION

Opening Addresses

Chairperson

H. BLIX
IAEA

OPENING ADDRESS

H. Blix
Director General,
International Atomic Energy Agency,
Vienna

The nuclear accident at Chernobyl on 26 April 1986 had a heavy impact on life, health and the environment. It caused agony to people in Ukraine, Belarus and Russia and anxiety far away from these countries. The economic losses and social dislocation were severe in a region already under strain. I think our thoughts at the opening of this Conference should first go to the many people who have suffered, or may yet come to suffer, as a result of the accident. I propose that, as a tribute to the countries and people affected, we begin our Conference by standing up for a minute of silence.

* * *

At the outset of this Conference let me further note that, although much help has been rendered by public and private organizations to alleviate the situation, there continues to be a crying need for further assistance to the peoples and countries to whom the consequences of the Chernobyl accident are a formidable burden added to an already very difficult situation. We urge such assistance.

If the first reaction must be one arising from human solidarity, our second reaction should be a demand for rigorous scientific analysis. The errors in technology, organization and management, which caused the accident, must be identified to prevent any repetition and the damages caused by the accident must be accurately assessed and diagnosed so that rational remedies may be applied.

The causes of the Chernobyl accident are by now rather well traced and identified. Only a few months after the accident the IAEA organized a major conference at which nuclear experts from all over the world were enabled, here in Vienna, to hold a first thorough discussion of the matter. Since then, further information has been forthcoming and improved our understanding. As a result of analyses undertaken, important technical, managerial and regulatory steps have been taken with regard to all Chernobyl-type (RBMK) reactors.

Other lessons from Chernobyl have prompted the conclusion of new international conventions. Already in 1986 the General Conference of the IAEA adopted one convention concerning emergency assistance in case of a nuclear accident and another convention to ensure that instant information would be available to facilitate protective measures in case of any future nuclear accident. Two years ago, a general international convention on nuclear power reactor safety was adopted, which we expect will soon come into force. Through these and many other measures, including new international safety services, governments and utilities have gradually sought to put in place a global nuclear safety culture that will reduce the risk of accidents occurring and mitigate the consequences of any accident that may yet occur. As safety is not a static concept, this culture will continuously evolve with new technology and experience.

Let me mention yet another example of lessons learned. After the Chernobyl accident the public was confused by governments applying widely diverging standards as to what constituted an acceptable level of radioactivity in different types of foodstuffs. Strawberries which could be safely eaten in one country could be rejected in another, etc. After considerable work, uniform international standards are now available.

The Conference which we open today is not focusing on the causes of the Chernobyl accident but on the consequences of it, a subject on which many investigations have been made but on which less consensus has been available. Yet, if decades of painstaking scientific research has brought a large measure of important knowledge and consensus about the consequences of the nuclear bombing of Hiroshima and Nagasaki, it should also be possible, by applying respectable scientific methods, gradually to attain a consensus about the consequences of the Chernobyl accident. To move towards such consensus is the aim of this Conference.

Much work has been done in the past ten years — not least by the three organizations sponsoring this Conference — to compile relevant data and to analyse them. Under the guidance of an international scientific committee the IAEA, together with a large number of sister organizations, in 1989 embarked on the International Chernobyl Project to assess the measures taken to enable people to live safely in areas affected by radioactive contamination. It involved more than 200 experts from 23 countries and was the beginning of an ongoing co-operation with the intergovernmental organizations represented here today. The conclusions of this early assessment, which were submitted to global expert discussion in 1991, have been generally sustained by subsequent scientific inquiries. In updated form they will be reviewed by this Conference. One of the conclusions of this early inquiry, namely that an increase in the incidence of thyroid tumours could be expected, seems tragically to be borne out by subsequent data.

The sessions of this Conference will also provide extensive information about and opportunity for discussion of the large scientific programmes of the World Health Organization (WHO) and the European Union (EU), in particular of the major technical conferences organized by WHO in Geneva in November 1995 and by the European Union, Belarus, the Russian Federation and Ukraine in March 1996 in Minsk. This Conference will also be familiarized with the work done by the United Nations, UNESCO and others. Much work relating to the consequences of the accident naturally consists in efforts of alleviation rather than investigation. Let me mention, as an example, the countermeasures developed through an IAEA–FAO project, sponsored by the Norwegian Government, to lower the levels of radioactive caesium in cattle by administration of an inorganic compound known as 'Prussian Blue'.

During this week a wealth of material will be presented and laid open for international discussion and critical analysis. Responsible Ministers from Belarus, the Russian Federation and Ukraine will inform the Conference on the social, economic, institutional and political impact of the Chernobyl accident.

I would like to pay tribute to the many people who have put so much effort into the preparatory work of the Conference. I have in mind scientists of the co-sponsoring organizations and many scientists from the three Republics, who have worked, over the last year in particular, to bring the results of their ongoing work to a point at which it could be reported here.

To facilitate the discussions of the Conference, background papers on key issues have been prepared. They are the result of months of work by teams of scientists from around the world to assemble and present the current state of knowledge in these key areas. Altogether 34 scientists worked on the six papers produced in this way. I express my thanks to them. I also want to thank the distinguished scientists on my right — Academician Illyin, Professor Rolevich and Dr. Kholosha, the members of the advisory committee who monitored all aspects of the preparation of the Conference.

It would be unrealistic to expect consensus among the scientists here on all issues presented. However, it might well be possible, on the basis of the scientific data now available, to reach broadly supported answers to many of the principal questions which have been publicly discussed in the past years. If so, this Conference will have served, ten years after the Chernobyl accident, to solidify our knowledge and understanding of the consequences of the accident and thereby help to better alleviate them.

It will be the arduous task of the Conference President, the Minister for the Environment, Nature Conservation and Nuclear Safety of Germany, Dr. Angela Merkel — herself a physicist by education — to prepare, with the assistance of a bureau of senior scientists, conclusions and recommendations arising from your discussions. I warmly thank her for undertaking the task of chairing the Conference.

OPENING ADDRESS

B. Boutros-Ghali
Secretary-General of the United Nations,
United Nations,
New York

This is a sombre anniversary. On the tenth anniversary of the accident at Chernobyl, the extent of its impact on affected populations has only begun to be fully realized.

The consequences of the Chernobyl accident cannot be regarded as the problem of a few countries. Even today, its health, social, economic and environmental dimensions, both immediate and long term, remain to be defined. The United Nations system, international organizations and member countries have responded to the need for help with compassion, energy and enthusiasm. Your presence in Vienna reflects this. The International Atomic Energy Agency, the World Health Organization, the European Commission and many others have played a key role in providing assistance. Within the United Nations, the Department of Humanitarian Affairs is bringing together all who are involved in addressing the Chernobyl issue in a necessary and valuable pooling of expertise and experience.

I welcome this international forum on Chernobyl in Vienna and hope that it can assist the affected States, as well as donor countries and organizations, to focus their relevant activities and assistance on the most pressing tasks, for much more needs to be done to help those still suffering.

This worst disaster in the history of nuclear power generation has displaced hundreds of thousands of people and severely affected the social fibre of the States that were most seriously affected by its consequences. Radioactive contamination, and health risks, both physical and mental, continue to affect vast populations in these countries. More than 300 children have been diagnosed with thyroid cancer. The fertility rate has declined dramatically, and the mortality rate has increased.

As I stated in my Annual Report on the Work of the Organization — 1995, lack of funds has affected several programmes relevant to addressing and mitigating the consequences of the accident. However, generous financial support by some countries has allowed the full and rapid implementation of priority activities.

The joint efforts of FAO and IAEA have rendered large areas of land safe for agricultural production. The UNESCO programme to overcome the psychological effects of the accident, however, continues to depend upon assured funds. The need for funds is also affecting the WHO International Programme on Health Effects of the Chernobyl Accident.

Each of these programmes and activities represents the potential of the United Nations for serving the international community in cases of great need. This Conference can do much to draw attention to and attract support for this work.

The deliberations of this Conference can facilitate a common understanding of the causes and consequences of the Chernobyl accident and promote the consolidation of international understanding on an issue the ramifications of which, even ten years later, still remain to be fully understood.

I wish you every success in your deliberations.

OPENING ADDRESS

H. Nakajima
Director-General,
World Health Organization,
Geneva, Switzerland

As a co-sponsor, the World Health Organization would like to thank you all very warmly for your support and participation in this International Conference. WHO highly appreciates this opportunity to share the considerable knowledge that now exists and to make a joint assessment of the consequences of the Chernobyl accident. Today, ten years after this disaster, many people are still suffering from its radiological and psychological consequences. We cannot afford to ignore the scientific and political lessons to be drawn from this tragic experience. One major objective of this Conference is to provide decision makers with the scientific evidence they need in order to make the most appropriate political and technical choices to improve nuclear safety and preparedness.

Following the Chernobyl accident, WHO took part in relief operations and scientific investigation as soon as international help was requested by the authorities of the former Soviet Union. In June 1989, WHO sent a team of scientists to Chernobyl, soon followed by expert missions from the League of Red Cross and Red Crescent Societies. In October 1989, the Government of the USSR formally requested the International Atomic Energy Agency to carry out an international expert assessment. The International Chernobyl Project, in which WHO has been an active partner, has provided invaluable information on the accident, its scope and consequences.

In addition, WHO has directed its main effort towards the mitigation and evaluation of the health impact of the accident, within the context of the International Programme on the Health Effects of the Chernobyl Accident (IPHECA). IPHECA started in mid-1991, after it was endorsed by the Forty-fourth World Health Assembly in resolution WHA 44.36. The pilot phase of this programme was planned to last four years. It was conducted with the strong support and involvement of the governments and scientists of the three countries most affected, namely Belarus, the Russian Federation and Ukraine. Major financial support was received from the Japanese Government and additional funding was provided by the Governments of Switzerland, Finland, the Czech Republic and the Slovak Republic. Progress reviews of the implementation of the pilot phase were carried out by WHO's Executive Board, first in January 1993 and then in 1995.

The technical part of IPHECA has consisted of five pilot projects covering, respectively: haematology, thyroid, brain damage in utero, epidemiology registry, and oral health in Belarus. Initiated between 1991 and 1992, these projects for the most part were completed by the end of 1994. IPHECA's objective was to support national efforts in dealing with priority health issues. The programme was also instrumental in improving and harmonizing health approaches, helping to develop common protocols. Finally, IPHECA contributed to the implementation of national activities by facilitating the provision of medical equipment, training and expert advice. During the pilot phase, nearly US $15 million, that is close to three-quarters of the total amount of funds made available, were spent on the procurement of medical equipment and supplies. In helping to develop, validate and strengthen methods, instrumentation and expertise, the pilot projects have provided strong foundations for the longer term co-operative effort which we need.

The pilot projects have covered an area with 270 000 inhabitants. Monitoring of the residents has included examination of children for detection of thyroid diseases, and a multitude of other examinations for most residents. Comparisons were made with data available for the period prior to the accident and results obtained in non-contaminated territories. A comprehensive report is now available on the scientific data obtained during the pilot phase of IPHECA.

In Novemer 1995, WHO convened a major international conference in Geneva, on the subject of the "Health Consequences of the Chernobyl and Other Radiological Accidents". The Conference focused on IPHECA's results and observations, and also took into account data from other radiological events.

The commemoration, in 1995, of the fiftieth anniversary of the devastation of Hiroshima and Nagasaki by atomic bombs was the occasion to call attention to the longer term health effects of nuclear radiation. To this day, many scientists from Japan and several other nations around the world continue to monitor and evaluate the health effects of the atomic bombing. I wish to pay tribute to their work and thank them for their co-operation in making their findings available to us, thus facilitating our assessment and understanding of the Chernobyl accident and its consequences.

The Chernobyl accident took the lives of 30 workers, most of them exposed to radiation while attempting to control the accident and its immediate impact. It also caused the hospitalization of hundreds of other emergency workers and exposed five million people to radionuclides. So far, this has led to a sharp increase in thyroid cancer incidence, especially among children living in the contaminated areas. The lives of most of these children could be saved by operation and medication. The evolution of other longer term effects will require further studies and close follow-up.

Apart from radiation induced effects, many people have also suffered psycho-social stress and significant disruption in their lives, affecting their physical and mental health and well-being. Originally, there was a great deal of fear and mistrust because of lack of information immediately after the accident. Since then, massive efforts have been made by the governments and health authorities of Belarus, the Russian Federation and Ukraine, to mitigate the effects of the accident.

WHO contributed to the public information effort by publishing and distributing a booklet giving facts about radiation and health. Major programmes are also being implemented by the IAEA, UNESCO, UNICEF and UNSCEAR, and certainly more work will be needed in this area.

International co-operation must be maintained and enhanced so that we can continue to improve our understanding and our ability to mitigate the consequences of the Chernobyl accident. The problems caused by radiological events quickly become global. The United Nations and its agencies can play a crucial role in ensuring prevention, preparedness, control and rehabilitation in case of a nuclear emergency. WHO is ready to continue to fulfil its responsibility and play a leading role in facilitating relief, research and technical co-operation in the field of health and radiation.

The International Programme on the Health Effects of the Chernobyl Accident (IPHECA) and the Radiation Emergency Medical Preparedness Network (REMPAN) have been reviewed and updated for continuation. I should like to take this opportunity to encourage all international organizations, governments and non-governmental organizations to join us in our efforts and to support them.

In this spirit, I wish to extend a cordial welcome to all participants and my best wishes for fruitful discussions during this international conference.

OPENING ADDRESS

H. Tent
Deputy Director-General,
Directorate-General for Science, Research and Development (DG XII),
Brussels, Belgium

It is an honour and a pleasure to be here in Vienna at the start of this important international conference. I wish to express, on behalf of Commissioner Madame Edith Cresson (Science, Research and Development) and Commissioner Mr. Van den Broek (External Relations with Central and Eastern Europe), our sincere hopes that this conference will be an outstanding scientific success and will benefit all those affected by the Chernobyl accident.

The explosion and fire at Unit 4 of the Chernobyl nuclear power plant on 26 April 1986, almost ten years ago, spewed large amounts of radioactive materials high into the air, leading to widespread contamination of large areas of Belarus, Ukraine and the nearby parts of the Russian Federation. Within a few days of the accident a low level of radioactive contamination had covered most of Europe and caused understandable, widespread alarm, which was also due to problems in the verification of the radiation effects.

In addition to the regulatory initiatives taken by the European Commission, the initial response of the European Union within the frame of its Radiation Protection Research Programme was to consider the short term consequences of the accident for the member countries of the European Union. This assessment, carried out over the period 1988–1990, was reassuring, but the accident and the general response to it had highlighted a number of problem areas in radiation protection which had not been given sufficient attention. Examples are radioecology in seminatural environments, decontamination strategies, the general use of bone marrow transplantation for the treatment of overexposure, and emergency management response, including the return to acceptable living conditions in highly contaminated areas.

In 1991, the European Parliament made available an extra budget to support research on radiation protection issues in and around Chernobyl. A Chernobyl research programme, conceived as a collaboration between European researchers and scientists of Belarus, the Russian Federation and Ukraine, was implemented. This collaboration was brought under the umbrella of the Agreement for Collaboration between the Commission and the Ministries or State Committees on Chernobyl Affairs of the three republics which was signed in June 1992. In the period between 1991 and 1993, sixteen collaborative research projects were initiated. For each of the projects a consortium, made up of institutes in the European Union and in the three republics, was established. Especially in the beginning, the collaborative work within the consortia was not always easy, but the European Commission believes that in general the experience has been extremely rewarding.

The major objective of the programme initiated by the European Commission was research in such areas as: the occurrence of cancer in children and Chernobyl cleanup workers; the behaviour of radionuclides in different environments and their transfer into the human food chain; the scientific basis for intervention in food supplies and for evacuation of contaminated areas; and the improvement of emergency management approaches.

The scientific findings and achievements coming out of the sixteen projects have been discussed in Minsk, three weeks ago, at the First International Conference on the Radiological Consequences of the Chernobyl Accident, jointly organized by the European Commission and the Ministries on Chernobyl Affairs of the three republics. This conference was attended by 850 scientists from over 35 countries and I am convinced that the results will contribute to the long-term strategies that are being developed in order to minimize the consequences of the accident and in order to restore acceptable living conditions in the less heavily contaminated areas. A more detailed presentation of the scientific and strategic outcome is scheduled for this afternoon, but allow me to mention some more general, but no less important, accomplishments.

One of these is the extremely constructive collaboration which has been established, first of all at the individual scientist level, where I know that mutual respect and many friendships have developed, but also extending to those who have been involved in the management aspects of the programme, acting at the level of the Co-ordination Board and the Management Group.

Another notable accomplishment has been the influence that the programme has had on the improvements to the local scientific infrastructure. Belarus, Ukraine and the Russian Federation are all going through a difficult transition period and there is a need to preserve and consolidate their scientific infrastructure which should be considered as a special resource for the new societies. The contribution of the programme to this end is of course not large in absolute terms, but, I believe, nonetheless significant. Probably the most important general achievement has been the opportunity offered by the programme for the training of younger scientists in some specialized institutes in the European Union. The future of science in the three republics lies with today's young scientists and the problems of Chernobyl will not be solved in the next few years. I hope that these younger scientists will go on to utilize the extra skills they have acquired to the greater benefit of the people living around Chernobyl and who have been affected by the accident.

Through a collaboration with ECHO, the European Community Humanitarian Office, and TACIS, the Technical Assistance to the Commonwealth of Independent States, the immediate health care was improved. ECHO provided essential medical equipment for the diagnosis and treatment of childhood thyroid cancer and TACIS enabled training of medical specialists, and financed the manufacturing of the thyroid drug, L-thyroxine, and of iodized table salt for household use.

The first phase of this collaborative programme is coming to an end. The services of the Commission are at present evaluating proposals received within the frame of the Nuclear Fission Safety and Inco-Copernicus programmes. I can assure you that we in Brussels are doing all we can to put together a package of collaborative research that will ensure the continuation and consolidation of the past efforts.

The improvement of our scientific relations has fostered a new era of co-operation which will allow us to work together to ensure better protection for the population and the environment and to promote greater security for peaceful nuclear activities. The willingness to draw clear and objective scientific conclusions may contribute to create a spirit of openness and 'transparency' necessary to increase public acceptability which is a key factor for the use of nuclear energy.

Before closing my short address, I would like to take this opportunity, on behalf of the European Commission, to thank the organizers of the conference for all their hard work, and the participants for ensuring the success of this meeting.

OPENING ADDRESS

Y. Akashi
United Nations Department of Humanitarian Affairs,
New York, United States of America

Presented by M. Griffiths

It is my privilege and pleasure to address this forum on behalf of the United Nations and its Department of Humanitarian Affairs. First of all, let me express, on behalf of Mr. Yasushi Akashi, the United Nations Co-ordinator of International Co-operation on Chernobyl, our appreciation to the IAEA, the European Commission and WHO, which have helped organize this conference and remain key organizations in assisting the countries affected by the Chernobyl disaster.

Mr. Akashi has asked me to convey to all of you his best wishes for a successful conference which will help refocus the world's attention on a tragedy that will be with us long into the next century.

The word Chernobyl no longer represents merely a place in the Ukraine, it no longer even represents a particular nuclear power station. It has become, in many languages, a word heavy with the implications and images of dangerous technology beyond control, of lifeless cities and villages and of immense human suffering and fear.

It is no exaggeration to say that this disaster is unique in history, in part because the full nature and extent of its harmful effects are still not clear, and its consequences will reach far into the future.

For Ukraine, for Belarus and for parts of the Russian Federation, Chernobyl has meant ten years of contamination and contamination risks, of forced displacements and the persistent scrutiny of researchers, of conflicting reports and growing scepticism by various authorities.

Sadly, the plight of these communities has been met with increasing ambivalence on the part of the international community.

Other speakers will give details of some of technical aspects of the disaster. My concern today is humanitarian. Let me briefly sketch the outlines of the humaritarian catastrophe we call Chernobyl.

The three affected countries officially estimate that, overall, at least 9 million people have in some way been affected by the Chernobyl disaster.

The minimum estimate for the number of people forced to leave their homes because of radiation danger following the Chernobyl explosion is almost 400 000: 150 000 in Belarus, 150 000 in Ukraine and 75 000 in the Russian Federation.

These internally displaced persons have suffered the hardships of other refugees: they were forced to flee their homes and established community structures at very short notice, unaware of where they were going or how they would end up, and having to live in temporary shelter and endure extremely poor living conditions.

Chernobyl and its aftermath meant the diversion of enormous financial resources, hampering the work of national governments attempting to cope with new political systems and the transition to market economies.

Although the accident occurred in April 1986, it was only in 1990 that the authorities involved appealed for international assistance. The United Nations was, from the outset, specifically mandated to study, mitigate and minimize the consequences of the Chernobyl disaster.

The overriding objective of the United Nations system has been to achieve the most effective results in dealing with health, social and environmental after-effects.

The Secretary-General launched a vigorous campaign to mobilize resources and international co-operation, not only for the direct victims of the accident but also, in a more comprehensive way, to deal with at least some of the broader social and economic effects. He established a United Nations Inter-Agency Task Force for Chernobyl to ensure rapid decisions on policy and substantive questions. It comprises representatives of those agencies and organizations which can provide direct and relevant assistance and advice, particularly in the critical sectors of health, agriculture, environmental protection, energy planning, resettlement, education and public information, industry and infrastructure, and nuclear safety.

The main mechanism for international co-ordination is the Qaudripartite Committee for Co-ordination on Chernobyl, which comprises the Under-Secretary-General for Humanitarian Affairs and the ministers responsible for Chernobyl-related affairs in Belarus, Ukraine and the Russian Federation. In recent years the annual Quadripartite Committee meeting has been expanded to include the participation of the European Union and agencies of the United Nations system.

As directed by a number of General Assembly resolutions, the United Nations has worked towards a more focused, pragmatic and straightforward approach to this problem. This has meant identifying and focusing on the priority needs, compiling specific projects by United Nations agencies to respond to these priorities and defining the time frames for their implementation.

Most importantly, the effort of the United Nations has sought to emphasize the human dimension of the aftermath of Chernobyl. The involvement of the United Nations is overwhelmingly on behalf of the victims.

Close co-operation and an effective division of labour has been essential, not only between the United Nations and the three affected States but also among the United Nations system and the European Community, the World Bank, bilateral donors, non-governmental organizations, industry, etc. The United Nations acted as a catalyst in this effort and assisted in bringing the various parties together.

A Joint Plan of Action was prepared which served as the principal document at a Chernobyl Pledging Conference held in 1991. Although sympathy for the victims of the accident has been universal and expressions of support numerous, the tangible assistance offered at the Pledging Conference and afterwards has been only modest.

I regret to tell you that the funds of the United Nations Trust Fund for Chernobyl have been practically exhausted and without further support from the international community the efforts of the United Nations may simply cease. The United Nations therefore calls on its members to show a genuine solidarity with the victims of this catastrophe by continuing to provide assistance, both financial and in kind.

In spite of serious financial difficulties, efforts to strengthen international co-operation on Chernobyl do not stop. At its 50th session the United Nations General Assembly adopted resolution 50/134 on "Strengthening of international co-operation and co-ordination of efforts to study, mitigate and minimize the consequences of the Chernobyl disaster". This resolution requests the Secretary-General to continue encouraging the regular exchange of information, co-operation and co-ordination between United Nations agencies and other organizations.

The resolution also requests the Secretary-General to appeal to member States to continue and intensify assistance to Belarus, Ukraine and the Russian Federation.

The General Assembly declared 26 April 1996 as the International Day Commemorating the Tenth Anniversary of the Chernobyl Nuclear Power Plant Accident. We look to commemorative events such as this conference and the Round Table in Kiev to encourage measures to alleviate the continuing impact of the disaster. And by measures, I mean provision of resources — funding in cash and kind — whether from bilateral or multilateral sources, through non-governmental channels or private sources.

Let me be quite clear on this point. The resources we were given are now virtually exhausted. The extent to which the United Nations can continue to relieve suffering and assist in the long process of recovery will depend on the extent of resources made available from now on.

If there was new funding, our main priorities would be (a) health, (b) improvement of the information to the population on the consequences of the catastrophe, as well as (c) the creation of additional socio-psychological support at the level of the communities in schools.

We believe that the tenth anniversary of the Chernobyl disaster on 26 April 1996 should lead the international community to remember the people affected by Chernobyl.

To ignore this continuing tragedy would be to reduce these people and the affected regions to mere objects of scientific research. On behalf of the United Nations Co-ordinator for International Co-operation on Chernobyl, I call the world's attention to the humanitarian dimension of this disaster. We hope that this conference will result in new and tangible pledges of support to reduce human suffering and increase the capacity of Ukraine, Belarus and the Russian Federation to cope with the long term effects of Chernobyl.

OPENING ADDRESS

A. Merkel
President of the Conference,
Federal Minister for the Environment,
Nature Conservation and Nuclear Safety,
Bonn, Germany

Almost exactly 10 years ago, on 26 April 1986, the worst accident in the history of the peaceful use of nuclear energy took place at the Chernobyl nuclear power plant. We all know that the reactor accident brought great suffering to the people affected. It had grave implications for the health and living conditions of large sections of the population in Belarus, Ukraine and Russia. Many hundreds of thousands of people had to be evacuated or relocated because the radiation in their region was too high. Large areas of land in Ukraine, Belarus and Russia were contaminated by radioactive deposits and could no longer be used for agricultural purposes.

Therefore, at the beginning of this conference let us think of the people who have been affected by the consequences of the accident. We feel great sympathy for the victims of this disaster.

At that time everybody asked one question and this will be in effect the central theme this week: ''Is the use of nuclear energy still justifiable, and if yes, under what conditions?''

You know that in my country I am committed to the peaceful use of nuclear energy, particularly with respect to the discussion on the climate. But precisely because of this, I face up to the question of the consequences and possible dangers of using this energy. That is why I was happy to accept the invitation to take over the presidency here.

At this point I would like to express my particular thanks to the organizers of this conference, the International Atomic Energy Agency, the European Commission and the World Health Organization, who made this conference possible.

This week's conference is an attempt to formulate a synthesis from the results of the meetings of the WHO in Geneva, the European Commission in Minsk and the International Forum on Nuclear Safety Aspects here in Vienna. Their statements, made by institutions with the most varying mandates, must be further developed into an overall statement. Valuable preliminary work has already been done here and I would like to thank the organizations involved for this.

It remains our task to clearly analyse the following points:

— What were the causes of the accident and have they been understood sufficiently?

— What bearing did the accident have as regards health, social and psychological matters, the economy and the environment?
— What conclusions have been drawn from the findings available so far?
— What remains to be done?

1. THE CAUSES OF THE ACCIDENT

The main causes of the accident were technology, followed by human activity. We must look into the question of the extent to which the particular features of the RBMK type reactor contributed to the disaster, whether and to what extent deficits in the reactor design were known and how the operating staff should have reacted to prevent excursion occurring at all. We expect answers to these points from the results of the Forum on Nuclear Safety Aspects mentioned earlier. In this connection, another important matter is the implementation of any conclusions for other nuclear power plants. Obviously the accident scenarios cannot be directly applied to reactors of completely different types from the one involved in the accident. However, we must do our utmost to ensure that an accident of this kind does not happen again.

The encasing of Unit 4 of the Chernobyl reactor has been a visible warning for 10 years. The safety of this sarcophagus is also an important subject here. The problem of the encasement or the disposal of the residual nuclear inventory must be solved once and for all.

2. THE ACCIDENT AND ITS CONSEQUENCES

The consequences of the accident as regards health, social and psychological matters, the economy and the environment will be a central theme of the conference.

In this part of the conference we are historians who will endeavour to portray neutrally — without understating or exaggerating — what happened or is happening. For many aspects, such as the long term implications of the accident for health, we can only present a snapshot image, just up to the present moment. Predictions will not be easy, but maybe this snapshot image will serve to show us that not all of our expectations have come about. However, neither have all our fears.

What has to be looked into are the effects on the reactor staff directly on the spot, including the fire fighters whose job it was to extinguish the graphite fire. These people were exposed to the highest doses. The medical care they received must be assessed from our current point of view, but with the level of knowledge of that time being taken into account.

With respect to the more long term effects on health we must look into the question as to whether the number of cases of thyroid cancer in children, which has been constantly increasing since 1990 — to date, more than 600 cases have been identified — is, in addition to the immediate consequences, the only effect which can be proven to be directly attributed to radiation exposure. We are horrified to see that it is children above all who must suffer. Even more, the type of thyroid cancer is very aggressive and we must ask ourselves whether the otherwise excellent chances of cure for thyroid cancer also apply here.

We must assess the epidemiological findings for other types of cancer, in particular with regard to leukaemia, which has always been thought to be the most sensitive indicator for exposure to radiation. There have not yet been any cases of leukaemia attributable to the disaster. What does this mean for the future? In this connection we will have to examine what this means for the development of other tumours or other health effects as the results of exposure to radiation.

The purely radiation induced effects were, at least in principle, known. After Chernobyl we have seen that the psychological consequences were comparatively underestimated. The population in the area affected is actually suffering from a number of illnesses that cannot be explained as having a direct *causal* link to increased exposure to radiation. We think that we know that these effects on health are psychological consequences of the accident, the general uncertainty about the actual situation, as well as other stress factors, e.g. resettlement. This was associated with a disruption of social networks. Several hundred thousand people were evacuated or resettled, with enormous social implications. At the same time we can see an increase in the accumulation of specific diseases — not yet regarded as radiation induced — particularly among children.

The consequences for the environment will include discussion of the dispersion of radioactive substances in ecosystems, issues relating to the pollution of soils, plants and animals, as well as current and future human exposure to radiation. The conference should also look into the effects on agriculture resulting from the prohibition of the further use of large areas of production as a result of radioactive contamination. In addition to this we should also look at the measures already implemented or to be tried out to reduce pollution in food.

The conference will also concern itself with the social, economic, institutional and political effects of the accident and will discuss the collapse of the social structures as the result of the evacuation of people and the subsequent stigmatization of the people evacuated.

The economic consequences of the accident for Russia, Ukraine and Belarus must also be examined.

3. CONSEQUENCES OF THE ACCIDENT

It is not enough merely to list the consequences of the accident. We must rather ask whether we have drawn the right conclusions.

In the field of nuclear safety, the design and functioning and safety features of reactors, we can build upon the preliminary work of the International Forum on Nuclear Safety Aspects.

The conclusions drawn from Chernobyl naturally include the obligations under international law and in the international community, such as the two Vienna Conventions of 26 September 1986 on Early Notification of a Nuclear Accident and on Assistance in the Case of a Nuclear Accident or Radiological Emergency. International co-operation in the field of nuclear safety had and still has the priority goal of ensuring nuclear safety *worldwide* at a high level. Everybody involved knows that there must not be a second Chernobyl.

Great efforts were made in the East to overcome the consequences, with a great deal of support from the West. Here we should also address the mistakes and deficits on both sides, East and West.

The assistance provided by the West should be looked at critically, as to whether sufficient help was given or whether it sometimes missed the target. Western consultancies were paid quite considerable sums for their activities. There is nothing wrong with this. But I cannot understand that there was not enough money to provide the children suffering from thyroid cancer with the medicine they need.

We should quite clearly deal with the measures to be taken in the event of an accident. In spite of high safety standards at nuclear power stations we cannot completely exclude an accident. What is decisive then is to inform the public openly and transparently. In comparison to the previous purely radiological way of looking at things, in the future the social and psychological aspects must be given much higher priority.

4. PERSPECTIVES FOR FURTHER ACTION IN THE FIELD OF NUCLEAR SAFETY AND RADIATION PROTECTION

We must derive the perspectives for the future from all the findings we have in front of us.

For the field of nuclear safety this means the dynamic further development of the safety standards of all nuclear power stations. Nuclear energy only has a future if safety is a top priority. If reactors do not meet the internationally recognized safety requirements they must be retrofitted or, if this is not possible, closed down. This is also an obligation from the Nuclear Safety Convention which all the relevant countries have signed.

In the field of radiation protection, deficits have become manifest in some areas. These must be overcome where they still exist. This applies particularly for the acute phase after an accident, in the field of emergency measures, radiation medicine and radiation biology.

I have already pointed out that we still have deficits in our knowledge about the effects of ionizing radiation, regardless of the fact that we know a great deal in comparison to what we know about other noxious substances. Further studies on varying radiation sensitivities of different individuals must be carried out: in particular the risk groups, including children, must be observed intensively.

I believe that the reactor disaster also made the following very clear: If we think in particular of the great consequences in the psychological area, then an improvement of emergency management, considering the aspects of international harmonization measures and acceptance in the special situation, is urgently required.

Finally, we must permit ourselves the question as to whether the Chernobyl reactor accident covers a dimension which goes far beyond the boundaries of the areas of nuclear safety and radiation protection. The actual effects of this disaster have social and economic aspects which are possibly far more significant than radiation exposure itself.

Ladies and gentlemen, in this week we have the opportunity as well as the duty to ask ourselves the questions associated with the further use of nuclear energy and to formulate answers.

Only if we succeed can we finally find an answer to the question as to what conditions should be imposed in order to ensure that the future use of nuclear energy remains responsible.

When the accident in Chernobyl took place the world was still divided. There were two large political camps which were separated by an iron curtain. From my own experience I know what this meant for people. Today we can talk openly about the past. I call upon you to do so.

OPENING SESSION

National Statements

Chairperson

A. MERKEL
Germany

NATIONAL STATEMENT

A.G. Lukashenko
President of the Republic of Belarus,
Minsk, Belarus

I am profoundly grateful to the organizers of the conference for the invitation and for the opportunity to take the floor before the scientists, statesmen, public figures and representatives of international organizations who are gathered at this representative forum.

The invitation to the conference and participation in it of a representative Belarusian delegation is convincing evidence that the world community is aware of the fact that the people of Belarus bear the main burden of the consequences of the Chernobyl global disaster.

According to international estimates, it is Belarus that received the greater part of the radioactive fallout and every fifth person in Belarus has felt the consequences of the Chernobyl accident.

After the disintegration of the Soviet Union we were left alone with this disaster. The consequences of the catastrophe coincided with the economic crisis, with the destruction of the former public and political structures. That is why we have to resolve a *multitude* of socioeconomic problems, to construct a young State of Belarus while doing everything at the same time in order to minimize somehow the consequences of the Chernobyl catastrophe. And it is extremely difficult for a single country to cope with it, taking into account the global character of the disaster, the more so because the Chernobyl tragedy occurred in the territory of a neighbouring and friendly independent State. This nuclear power station was not built by us, it was not serviced by us and we did not have any influence on the processes taking place in it. And, psychologically, it is difficult for the people of Belarus to reconcile themselves with such high payments for the errors of others. As a result we found *ourselves* as if we were guilty although we are guiltless.

The Book of Books — the Bible — reads: **"And a great star ... fell from the sky on a third of the rivers ... The name of the star is Wormwood. A third of the waters turned bitter, and many people died from the waters that had become bitter."**

A bitter wormwood herb is called here in Belarus "chernobyl". The word itself — Chernobyl — has two stems and is translated as "black fact".

It is indeed a black fact of life, a sad reality for the peoples of Belarus, Russia and Ukraine and for the peoples of the whole world. This is a tragic lesson which, as never before, has brought us — the citizens of our planet — closer to each other and made us think about: How shall we survive in an atomic age? What will become of us in the after-Chernobyl epoch? Do we have enough knowledge and force to prevent in future any global catastrophes of this kind?

That is why politicians, scientists and public figures from different countries of the world after having learned from the tragic experience of Chernobyl must do everything possible so that it can never again be repeated.

I am confident that it can be done through our mutual understanding and mutual aid.

The participants of the conference, scientists and representatives of different countries of the world ought to understand in full measure the current plight of Belarus.

More than six thousand square kilometres of our territory, inclusive of about three thousand square kilometres of fertile arable land, were removed from economic use as a result of the global catastrophe.

According to our most modest estimates, the economic damage incurred following the Chernobyl accident is equal to 32 annual budgets of the Republic, i.e. US $235 000 million. For these purposes we allocate annually 20–25% of the State budget.

Although 10 years passed after the accident, the most polluted areas are still functioning in emergency regime conditions. I am convinced of that after visiting more than once the Chernobyl affected areas and meeting people living there.

In these places the people link their destinies with their native towns and villages and most of them are not going to live elsewhere. Even in these complicated social, demographic and psychological conditions our people succeed in manufacturing good quality and ecologically pure produce, in regulating their life in a new way. This gives us hope that the affected territories, given the goal-oriented support of the State, can be returned to full and viable life. On these lines we co-operate with the WHO, the IAEA, the European Commission and other international agencies. Our scientists and experts constantly study the situation in polluted areas.

On the basis of the scientific data obtained, the Government of Belarus has worked out a new State Programme which is based upon the contemporary insight into the different aspects of the solution of the Chernobyl problems, first of all upon the necessity to rehabilitate the affected regions.

Undoubtedly, when resolving such long-term problems **we will hardly be able to manage without precisely identified scientific guidelines and without the help of the world scientific circles.**

I urge you to look for new efficient ways and methods in order to return the affected areas to full and viable life. We need concrete targeted financial technological and methodological support from the international community.

It is necessary that the population of the affected areas should feel today **the real yield** from the current international projects. It is important for us to have a clear idea how, within the briefest period and with minimum costs, the Chernobyl problems will be resolved.

I am convinced that at this stage it is necessary to identify the most rational applications of international intellectual efforts and material means.

As President of the Republic of Belarus I would be grateful to the experts who are gathered here if an all-round discussion of this issue takes place at this conference. If we let the time pass, if we fail to create acceptable conditions for life in these areas they will be doomed to social, demographic and economic disintegration.

I am aware that side by side with scientists there are also present here many influential public figures, top politicians and financiers, and well known journalists — i.e. all those who are actively involved in shaping the public opinion and influencing the decision making in their countries and in international agencies.

I know that the Belarus leadership strategy of action on overcoming the consequences of the Chernobyl catastrophe finds understanding in the most authoritative international organizations. Of that I became convinced when I took part in the work of the First International Conference on Chernobyl Problems recently held in the capital of Belarus — Minsk.

I am sure that you also as participants of this conference will give your support to Belarus, will inform the world public of our problems, and will extend the necessary support.

A considerable part of the intellectual *resources* is used by Belarus in order to overcome the consequences of the Chernobyl catastrophe. In the past 10 years a network of specialized research institutes has been formed and qualified national scientific personnel have been trained.

Large-scale research is being conducted in the field of radiation medicine, genetics, radiobiology, agricultural radiology, and manufacturing of special preparations and food additives. There is active research into the problems of socio-psychological and economic rehabilitation.

In Belarus in the post-Chernobyl decade we have accumulated a unique experience on the results of radiation effects on human beings and the environment. We have fundamental scientific material on the reduction of negative effects of radiation.

We see that scientists of many countries, international scientific communities and agencies display interest in our scientific developments. In this sphere we proceed from the principles of free and guaranteed access to the information on the *consequences* of the catastrophe.

We are providing the necessary conditions for the implementation of international research projects in our territory. I believe that you will agree that the complete results of this research should be given to our country and applied for the purpose of overcoming the consequences of the catastrophe.

While carrying out joint work with scientists from western Europe and from other countries of the world, Belarus pays considerable attention, within the framework of the CIS as well, to the Chernobyl problems. This is done especially on the basis of bilateral co-operation.

The consequences of this catastrophe were also discussed by the Heads of States during the signing on 2 April 1996 of the Union Treaty between Belarus and the Russian Federation.

We understand that the Chernobyl accident, the *consequences* of which are defined as a ''national environmental calamity'' and even as a ''global catastrophe'', cannot be regarded only from a narrow professional standpoint of radiology and radiation safety.

Such large scale tragic consequences of the Chernobyl nuclear plant accident influence crucially all the spheres of active life not only in the affected areas of Belarus but also in many European countries and the whole world.

The United Nations General Assembly sized up the Chernobyl tragedy as a global radio-environmental catastrophe. The United Nations work on co-ordination, initiation and discussion of the issues related to Chernobyl problems. This is extremely important for us. I assure you that the activities of this authoritative international organization and its initiatives on rendering aid to the countries affected by the Chernobyl tragedy are highly appreciated by Belarus.

At the same time I consider it necessary to continue to look for new strategic guidelines in the field of international co-operation on Chernobyl.

In view of this it would be expedient to set up **a Uniform Scientific Interstate Centre** on the problems of Chernobyl. The Centre would combine the efforts of local and foreign scientists, it would increase the efficiency of their work and co-operation, and it would provide assistance for the creation in the affected areas of long-term scientific teams with a permanent technical basis. Also, it would be logical to arrange financing of the Chernobyl projects, both our projects and foreign ones, on equal and mutually accepted terms.

I also suggest setting up a **Fund of Planet Protection** which could accumulate some part of the multimillion profits of nuclear machine building and power engineering corporations in order to use these funds for the liquidation of the consequences of nuclear catastrophes and the implementation of environmental programmes.

We also regard as topical the problem of **the responsibility of States** for causing nuclear damage to other countries and creating an international legal framework which specifies the appropriate guarantees and compensations. As far as I know, the IAEA is already undertaking practical steps in this direction. We welcome this and call for the speediest elaboration of such an international instrument.

Given the importance of this forum, it seems to me that we, scientists and politicians, could also consider the issues on providing **stable socioeconomic and environmental development of Belarus** — a country with its economy in transition, facing extreme conditions because of the consequences of the Chernobyl catastrophe.

Over the past 10 years the international community has already been realizing step by step the bitter lessons of one of the most tragic events of the 20th century when this creation of human mind, built for the benefit of people, went out of control and scorched our earth with a radioactive tornado never seen before. And these lessons should be learned from in many more years to come.

For those who did not face directly the radiation disaster it may seem that the problem of Chernobyl has lost its intensity and topicality. But this is not so for the people of Belarus, Russia and Ukraine. Yet for a long time, during the lifetime of more than one generation, our people will have to make quite a substantial 'Chernobyl amendment' to all social and economic programmes.

However poignant the lessons and bitter the experience from the Chernobyl catastrophe are, these are the sufferings not only of Belarus but of the whole mankind. New scientific findings in this field notwithstanding, this has been a tragic experience, and not only for us. I am sure that the people of the whole planet to the same degree as Belarus need support and assistance from the international community in order to provide a sound future for present and future generations.

Belarusians are people who have never remembered any evil, but they always remember gratitude, because, as an excellent Austrian writer, Maria Ebner-Eschenbach, says, ''We are never so grateful for anything as for gratitude itself''.

I hope the work of the conference and your scientific activities will contribute significantly to overcoming the Chernobyl catastrophe's consequences.

I sincerely wish you success and fruitful work.

NATIONAL STATEMENT

S.K. Shoigu
Minister for Civil Defence, Emergencies and
Elimination of Consequences of Natural Disasters,
Moscow, Russian Federation

Ten years have passed since the accident at the Chernobyl nuclear power plant — the worst industrial accident of the twentieth century, when the consequences affected vast areas and millions of people. This accident exerted a profound influence on many countries' political decisions regarding the development of nuclear power, and left Russia, Belarus and Ukraine with a burdensome heritage: radioactively contaminated territories and the problems of both participants in the cleanup operations following the accident ('liquidators') and members of the population affected. In Russia alone, the total area of land radioactively contaminated at a density exceeding 1 Ci/km^2 of caesium-137 is over 56 000 km^2, inhabited by some 3 million people.

The shear scale of the Chernobyl accident made it a national tragedy for Russia as well as for Belarus and Ukraine. It had a powerful influence on the economic development of the territories affected, creating a number of difficult medical, ecological, economic, social and psychological problems. It caused changes in social consciousness, prompted the re-evaluation of many existing stereotypes, engendered new approaches to ensuring the safety of nuclear power installations, and led to the development and organization of measures for the social protection of the population living in the contaminated areas.

By the time of the Chernobyl accident, Russia had already acquired some experience with radiation protection for the population following the accident in the Southern Urals in 1957. However, this experience was found inadequate to deal with the scale of the Chernobyl disaster and the millions of people involved in it. The social and economic consequences of the Chernobyl accident have proved worse than the radiological ones. Moreover, the consequences have undoubtedly been greatly aggravated by changes which took place in the former USSR, such as perestroika and the dissolution of the Union.

Today it is obvious that the Chernobyl accident led to the degradation of economic life in the contaminated areas, destroyed the demographic structure of the population, and gave rise to a stable 'Chernobyl syndrome' in the population and among the liquidators, although the observable deterioration in their state of health is due to a complex of factors including economic, psychological and social ones.

Among the population of the contaminated areas a state of great anxiety and psychological discomfort has arisen. These stressful states have a tendency to develop into psychosomatic diseases.

An obvious effect of the radiation from the Chernobyl accident is the increased incidence of thyroid cancer in children and adolescents. So far, over a hundred such cases have been diagnosed in Russia, which is tens of times higher than the normal rate for the country as a whole. For the present, we see no growth in morbidity among the population due to leukaemia, malignant tumours or genetic defects. But this does not mean that they may not occur in the future.

The problems with the liquidators are getting worse, especially as far as their medical and social rehabilitation is concerned.

The Government of the Russian Federation, recognizing the seriousness of the situation, has since 1989 been conducting a number of special investment programmes in the contaminated areas aimed at improving the quality of life for the population.

Over the past years, trillions of roubles have been made available for the rehabilitation of the parts of Russia affected by the accident: more than two million square metres of residential housing have been built, as well as hundreds of schools, hospitals, medical centres, communal amenities, thousands of kilometres of roads and gas piping, and numerous industrial plants, especially small-scale facilities for the processing of agricultural produce. All this has brought some economic improvement in the districts affected.

There are also substantial achievements in the area of improving medical care for the affected population.

A number of major scientific, technical and industrial problems have been successfully resolved either wholly or in part. They include the establishment of a system for monitoring the contaminated areas, the preparation of maps showing the density of contamination of the land with radionuclides, and the observation of practically the entire territory of the Russian Federation where traces of the disaster may exist.

Problems of decontaminating settlements and the adjoining land have been solved. Agricultural technologies permitting 'clean' products to be obtained from contaminated land have been developed and introduced.

Considerable work has gone into reducing the radiation doses to the population. In the most heavily affected districts of the Bryansk province, the action taken, together with a number of social measures, allowed radiation doses to be reduced by a factor of more than three over the period 1990–1994.

Despite the limited successes achieved, the present situation in the parts of Russia affected by the accident is still not satisfactory. Let me give some figures.

More than 200 000 people took part in the 'liquidation' work to deal with the consequences of the Chernobyl accident. About 50 000 people were evacuated from the contaminated parts of Russia or left voluntarily. The entire population was evacuated from 17 settlements lying within the exclusion zone. Currently, over 2500 people still live in settlements with a contamination density exceeding 40 Ci/km^2. Some 20 000 hectares of agricultural land have been taken out of production, as have over 60 000 hectares of forests. Agrotechnical measures have been applied on 3 million hectares.

At the same time, some 100 000 people are exposed to additional radiation doses exceeding 1 mSv per year, and in four settlements the mean doses of additional radiation exceed 5 mSv per year. There are cases where the permissible levels for caesium-137 are exceeded in milk and dairy products from private farms. The deterioration in the economic situation of the country has led to an increase in the proportion of the population's diet accounted for by home-made products and wild mushrooms and berries. As a result, an increase in the internal radiation doses to the population has been observed in a number of settlements.

For this reason we plan to continue the measures to minimize the consequences of the Chernobyl accident by enhancing the quality of life of the population and the level of medical care, carrying out special measures to reduce the radiation doses to the population, and continually removing limitations on human activities in the contaminated areas. In this endeavour, particular attention is to be focused on high-risk groups — the liquidators of 1986, evacuated inhabitants, children and adolescents living in contaminated areas — and also on restoring life and normal economic activity in the worst contaminated territories of Russia, including those taken out of utilization.

An important problem remains the need to improve legislation on the radiological and social protection of the population living in the contaminated areas. The existing legislation does not take into account the improvements which are occurring in the radiation situation and does not allow normal socio-economic development of the regions.

Note that the radiation situation today in a number of districts affected by the Chernobyl accident is such that there is no longer any need to maintain their special status and continue special post-accident radiation protection measures for the population.

In 1995 the Russian Scientific Commission on Radiation Protection adopted a new concept for the radiation, health and social protection and rehabilitation of the population of the Russian Federation exposed to radiation from the accident. According to this concept, it is intended to make a transition from zoning the territory on the basis of the caesium-137 contamination density, which does not reflect the real impact and degree of radiological risk, to a solution whereby the medical and social protection of the population would be based on radiation doses accumulated over life.

In this light we see the following scientific research tasks ahead of us for the coming years:

- Further study and forecasting of the radiological consequences of the accident;
- Study of the psychological consequences of the accident and development of methods of restoring the psychological health of the liquidators and population;

— Development of methods of radiological rehabilitation and socio-economic revival of the most heavily contaminated areas, including the exclusion zone.

In conclusion, I should like to say that we are still far from having solved all the problems of mitigating the consequences of the Chernobyl accident. For this reason, we call upon foreign countries and international organizations to continue co-operating in this noble endeavour. We, for our part, are prepared to do everything to ensure that international contacts and links in this area become even more effective, that they are broadened and deepened, and that the experience from liquidating the consequences of the Chernobyl disaster is placed at the disposal of mankind as a whole.

We express our deep gratitude to the international organizations (European Commission, IAEA, WHO, UNESCO, etc.) and to the United States of America, Japan, France, Germany and other countries that are successfully co-operating with us in dealing with the consequences of the accident on our territory and providing help in solving this problem.

We think it is essential to continue working on the preparation of international documents on all aspects of the prevention of radiation accidents and the mitigation of their consequences, drawing on the lessons learned from handling major accidents, above all the one at Chernobyl.

The experience gained from the struggle against nuclear damage must become the general heritage of humankind and be used to man's benefit so that such a tragedy never occurs again in any other country or region.

NATIONAL STATEMENT

Ye. Marchuk
Prime Minister of Ukraine,
Kiev, Ukraine

The man-induced disaster at Chernobyl — unprecedented in its scale and consequences — the tenth anniversary of which has brought us together here, has imprinted itself in our minds as an event delineating two eras, so that the people of Ukraine talk about "before Chernobyl" and "after Chernobyl", these being completely different worlds. The accident at the Chernobyl nuclear power plant doomed millions of people to pain and suffering, alarmed them as to their children's future, affected their living environment and altered their psychological outlook.

It is up to us to do everything possible to eliminate or at least mitigate the consequences of the disaster and make the world aware of the lessons learned. The tragic experience we have acquired must serve as a warning to all mankind to ensure that Chernobyl is never repeated anywhere on Earth. In this way the suffering of the victims will not have been in vain.

The fire involving tonnes of graphite which followed the destruction of the reactor projected radioactive substances into the upper layers of the atmosphere, making the accident one of global scale.

Fire-fighting facilities capable of tackling the fire were not available in the former Soviet Union or anywhere else in the world, and this was an important lesson for the future.

The reasons for the accident were very complex, but, without doubt, one of the main causes was the defective design of the reactor, enabling such a dangerous object to be operated with an inadequate protection system. That, combined with the poor regulatory documentation, was the prime cause of the failure.

Over the last few years a series of measures has been undertaken to improve the different components of the reactor, increase nuclear and fire safety, and improve the quality of the operating manuals, with the result that the safety of the reactor and the whole plant has been greatly enhanced. The foundations have been laid for comprehensive nuclear legislation in Ukraine, and independent State bodies for regulating nuclear and radiation safety have been established. All this is helping to increase safety in nuclear power engineering in general.

The accident occurred on Ukrainian territory and it had to bear the brunt of the acute phase. In order to deal with the accident, vast technical resources were mobilized, including Army contingents, physicians and other specialists. Their accommodation, transport, dosimetric control and decontamination of the equipment, clothing and people engaged in the emergency operations involved vast effort and expense. In all, around 650 000 people took part in the emergency operations in the years 1986–1987.

People from all over the former Soviet Union took part in the operations. At the same time, Ukraine alone had to evacuate around 100 000 people and organize the continuous supply of concrete, liquid nitrogen and other materials for a period of several days.

The former Soviet Union possessed experience in dealing with a major radiation accident in the Southern Urals in 1957, but this was of limited value owing to the differences in scale and the types of radiation hazards involved. It has regrettably to be recorded that much of that which was known before the accident, in particular a series of special recommendations, was not made use of, which greatly exacerbated the consequences of the iodine release because of cattle grazing on contaminated land and consumption of milk by the population in the days and weeks immediately following the accident.

By dint of great efforts on the part of the liquidators and the associated support services, a special shelter, later to become known as the sarcophagus, was erected over the destroyed reactor. It was constructed in less than six months, thanks to great patriotic effort and literal human self-sacrifice and also thanks to the technical skills of scientists and engineers and the competence of Ukrainian design and construction organizations.

The sarcophagus is a very complex technical construction. It served to minimize the radioactive releases from the reactor, greatly improved the radiation situation at the site of the nuclear power plant and reduced the psychological stress among the population.

At the same time the sarcophagus is a ghastly heritage. There are around 200 tonnes of nuclear fuel enclosed within it. The maintenance of the sarcophagus and the solution of the problem of making it ecologically safe have placed a big load on the national budget, already burdened by the cost of dealing with the social and radiation consequences of the disaster.

An international competition for a project to deal with the sarcophagus, in which major European firms participated, served to show the extreme complexity of the problem. Its solution was beyond the capacity of even the biggest companies on their own and will inevitably require a consortium of engineering and economic resources.

In expressing its gratitude above all to the European Commission for assisting with a feasibility study on making the sarcophagus safe, the Government of Ukraine now appeals for the active collaboration of all to find an effective solution to this great problem.

Another major problem resulting from the accident is represented by over 800 radioactive waste burial sites which were created during the acute phase of the accident without any proper engineering preparations. These sites have been identified and plotted on maps, and engineering surveys and project work involving a number of European firms are now being carried out in this connection. The conversion of the temporary storage sites into a system of long-term radioactive waste repositories is a complex technical and economic task calling for our combined efforts.

One of the consequences of the accident qualifying it as a disaster is the contamination of large tracts of land. In Ukraine the contaminated areas amount to 50 000 km^2. 180 000 ha of agricultural land have had to be withdrawn from use and about 40% of the total forest area of Ukraine has been contaminated.

The critical products in most cases are milk and beef, which are responsible for up to 95% of human radioactive caesium intake.

The deployment of agricultural countermeasures in Ukraine, the majority of which derive from the appropriate IAEA recommendations on procedures following major accidents, has enabled us not only to avoid exceeding the relevant norms but also to introduce control levels for the contamination of various products which are 2.5 times lower than the maximum permissible values.

However, the fact remains that the caesium-137 content in agricultural produce in the contaminated areas is considerably greater than in the rest of Ukraine and in western European countries. Unfortunately it is not at the work place but at home that the population of the contaminated territories receives the bulk of the radiation dose resulting from the accident, and it is children who are the critical population group most subject to radiation effects.

It is imperative that we pursue joint efforts to improve the radiation situation for the inhabitants of rural regions.

The task of assessing the medico-biological consequences of the accident presents many difficulties. This is due above all to the complex factors involved, such as, on the one hand, objectively measurable dose burdens and environmental contamination levels and, on the other hand, social and psychological factors not amenable to qualitative evaluation, namely uncertainty as to the assessment of the situation, distrust of information provided, ignorance of objective information about the biological effects of radiation, as well as false rumours and other things which can generate stress, the body reaction to which is unpredictable and disproportionate to the degree of exposure involved.

There are now 360 000 liquidators living in Ukraine who require medical treatment or constant supervision, rehabilitation and compensation for damage of various kinds to their health. 35 000 of them are now invalids. In addition, 3.1 million people are living or lived on contaminated land in the year of the accident. That figure includes around one million children. In the post-accident period there has been a great increase in morbidity of the population. Cases of oncopathology of the thyroid have increased several times in children and adolescents in Ukraine. The total number of persons suffering from thyroid cancer in this age group is 542.

In Ukraine the regions most affected by radioactive contamination were those with very poorly developed infrastructure. Therefore the Government is directing resources principally towards improving living standards in those regions and raising them at least to the average level for the country. This includes improving the housing conditions and resettling people from the compulsory evacuation zone where the radiation dose exceeds 0.5 cGy/a. In the period 1986-1996 two million square metres of housing was completed and schools for 35 000 children and pre-school facilities for 10 000 infants were constructed. By organizing meals for children in schools and pre-school facilities with food products from clean regions it has been possible to reduce the internal radiation dose of children by several factors. The construction of hospitals with 2000 beds and polyclinics to handle 7000 cases per shift has considerably improved the medical care of the population.

In all, more than US $2500 million has been invested in major construction work.

Health cures have been arranged for children and adults outside the contamination zone, during which time they are carefully examined and given medical treatment. Social benefits in the form of extra payments help to improve the living standards of the population, enable people to go on holiday and to undergo rehabilitation courses.

The total expenditure on eliminating the consequences of the accident over the period 1992 to 1996 alone, paid out of the Ukrainian national budget, exceeds US $3000 million. In the budget for 1996, more than US $600 million is allocated for these purposes and such sums are likely to be required for many years ahead.

I also wish to refer to another matter of great concern, namely the question of closing down Chernobyl nuclear power plant. Here we should like to confirm our intention to close the Chernobyl nuclear power plant by the year 2000, as stated in the Memorandum of Understanding between the Government of Ukraine and the Governments of the G-7 countries and the European Commission. However, without financial assistance from the world community, Ukraine will not be able to go through with this on account of its difficult economic situation. It is to be noted that, after having opted to become a non-nuclear weapon State, Ukraine was promised financial support by several countries, but to date has not received enough aid to resolve this problem.

Today the conference on Chernobyl will consider and assess the consequences of the accident on the basis of all the factual data accumulated over ten years in many countries, principally in those most affected — Ukraine, Belarus and Russia.

One of the most important results of co-operation with scientists of the European Community in our opinion is the elaboration of unified criteria and approaches for assessing the main factors of the radiation situation and the harmonizing of models for predicting the long-term behaviour of radionuclides in the environment and calculating the absorbed radiation doses of all categories of the population affected by the accident.

In the course of executing various medical projects, our countries have introduced the most up-to-date methods for early diagnosis of thyroid cancer and for reconstructing the absorbed doses from stable chromosomal changes, as well as new ways of treating patients with acute radiation sickness and other developments.

The fact that European scientists have acknowledged the correctness of assessments of the main causes of the accident made by Ukrainian experts is of great importance for the socio-psychological rehabilitation of the liquidators and the population of the contaminated regions.

Many of the results of joint projects have already been used by our countries to mitigate the consequences of the accident and are helping the people to come to terms with the situation.

The Ukrainian Government has done everything possible to assist in the organization of co-operative ventures and is financing a wide programme of research and operations to eliminate the consequences of the accident.

The Chernobyl zone offers unique opportunities for conducting all manner of research on the consequences of nuclear and radiation accidents for the natural environment and also for systematizing the results of research on the effect of constant radiation exposure on the plant and animal world.

The Ukrainian Government appeals to all countries, international organizations and scientific research centres and laboratories to participate in setting up and operating an International Chernobyl Centre on Nuclear Safety, Radioactive Waste Management and Radioecological Research.

Joint work under the aegis of such an international centre would enrich the methodological arsenal, and increase the database for further theoretical and practical investigations in the fields of knowledge associated with the impact of radiation on nature and living organisms.

On the eve of the tenth anniversary of the tragic Chernobyl disaster the leaders of the G-7 countries will participate in a summit meeting on nuclear safety in Moscow. The Ukrainian side trusts that this coincidence will not pass unnoticed at such a high forum, to which the President of Ukraine, Mr. L.D. Kuchma, has been invited. Indeed, we hope that through the combined efforts of the Governments of individual countries and international organizations the world community will take positive steps to eliminate the consequences of the greatest technological disaster in the history of mankind.

We are confident of the mutual benefit of such co-operation and hope that the participants in the conference will share our opinion and do everything in their power to continue and develop this co-operation.

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Updating Session 1

IAEA UPDATING REPORT ON THE "INTERNATIONAL CHERNOBYL PROJECT" AND THE PROJECT "ONE DECADE AFTER CHERNOBYL: ENVIRONMENTAL IMPACT ASSESSMENT"

INTRODUCTION

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Over the last ten years, the IAEA has had an extensive record of involvement in issues relating to the consequences of the Chernobyl accident. Some of this audience will no doubt recall the Post-Accident Review Meeting held at the IAEA a few months after the accident, at which representatives of the USSR unprecedentedly reported to the international community on the causes of the accident. Several other major projects have been carried out in the intervening period. However, in this Updating Report, two major pieces of work will be presented: a recapitulation of the results of the International Chernobyl Project, carried out in 1990 by an International Advisory Committee, for which the IAEA acted as Secretariat; and a presentation of work nearing completion on One Decade after Chernobyl: Environmental Impact and Prospects for the Future. This latter project has been carried out primarily by the Institut de protection et de sûreté nucléaire (IPNS) in France under the auspices of the IAEA, and at the request of the Government of Belarus to the 1994 IAEA General Conference.

This report is presented on behalf of the IAEA by three persons eminently qualified to introduce these studies: Prof. F.A. Mettler from the University of New Mexico, who was a member of the International Advisory Committee for the International Chernobyl Project and led the team for the health impact of the accident; Dr. D.G. Robeau from IPSN, who was the project manager of the IPSN study; and P. Hedemann Jensen of the Risø National Laboratory, who was a member of the team studying protective measures for the International Chernobyl Project and who has chaired the Supervisory Committee for the recent study.

OVERVIEW OF THE INTERNATIONAL CHERNOBYL PROJECT: HEALTH EFFECTS

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Thank you very much for the opportunity to present an overview of the International Chernobyl Project conducted during 1990, about 4½ years after the accident. I shall confine myself to the Health Effects portion of the Project. It is difficult to review about 20 person-years of work in 20 minutes. I shall try to place the project in the context of 1990 as well as its place today.

Data for patients were collected while I was working with local and national physicians from Belarus, Russia and Ukraine. The Health Effects portion of the Project was estimated to cost at least two million US dollars. The Government of the former USSR provided travel and housing, and the IAEA provided logistical support; however, the lion's share of the Project costs was borne by the individual physicians, scientists and universities who donated their time, as well as by various companies who donated the needed medical equipment and supplies.

Both the International Red Cross and the World Health Organization had sent health assessment teams to the area in 1988–1989. These were relatively small projects, but they reached essentially the same conclusions as we did.

The Health Effects portion of the International Chernobyl Project represented the combined effort of hundreds of physicians and scientists from many countries: Argentina, Australia, Austria, Germany, Greece, Japan, Netherlands, Sweden, United Kingdom, United States of America and Yugoslavia.

The teams included experts in internal medicine, endocrinology, haematology, oncology, pediatrics, immunology, radiation effects, foetal malformations and genetics, radiation cataracts, epidemiology, psychology and psychiatry, and nuclear medicine.

The Health Effects Team had a number of charges, which included:

— Review and analysis of existing data;
— Determination of the present state of health;
— Determination of which health effects might be due to radiation;

— Determination of the health effects due to the accident but not due to radiation per se;
— Estimate of future consequences.

The Project was difficult because of the very large area of heavy contamination that extended for hundreds of kilometres from the reactor site. Ultimately, the Project was designed, using an age-matched cohort comparison from nearby non-contaminated settlements.

The Project was specifically designed to study issues related to persons still living in highly contaminated territories. These persons were continuing to receive radiation exposure and there were pressing issues related to intervention and potential dose reduction. It was well known that there were hundreds of thousands of emergency workers who had been exposed, but in 1990 there was no possibility for dose reduction in these groups.

There have been a number of publications relative to this Project, including brief summaries and overviews. The Technical Report on the Project has 640 pages. The extensive scientific explanation, the limited availability and the price of the Technical Report have undoubtedly deterred many people from actually reading it. Summaries are the most commonly available literature on this Project and it is these that have been read by the public and media. It is upon these very abridged documents that statements and judgements have all too often been made. Unfortunately, it is not possible to include all data in a summary, and some summaries have suffered from inclusion of what the writers and editors thought was important at the time. I confine my comments in this presentation to the Technical Report. I would hope that persons with a serious interest in this subject obtain and read the actual Technical Report that was approved by the International Advisory Committee.

As with any project, there were strengths and limitations that were recognized even in the design stages. The strengths of the Project were:

— Participation of expert physicians from many nations who were not employed by nuclear industry or agencies;
— There was a wide multidisciplinary approach;
— Study subjects were chosen on the basis of the date of birth;
— Age-matched control populations were available in nearby non-contaminated areas;
— Entry of data was done by persons who had not collected the data;
— There were extensive and redundant quality control measures;
— Data were not analysed by the persons who had either designed the project or collected data.

The data were independently analysed in Hiroshima at the Radiation Effects Research Foundation by Dr. Mabuchi and in the United Kingdom at the Imperial Cancer Fund by Dr. Beral.

The weaknesses of the Project were:

- It applied to a single time point (1990);
- The sample size limited detection of entities that were of low prevalence or that had a low relative risk from the radiation;
- It applied only to rural populations in contaminated territory and not to emergency workers (liquidators);
- Some background health data were poor or not given by authorities to the team members in spite of requests;
- It was essentially a screening study of clinically observable effects, even though some haematological and biochemical data were obtained.

From a review of the data obtained by scientists, it was clear that there were a number of prior health studies that had been performed without the necessary control groups, quality control parameters or bias elimination. There were also studies which had been carefully done and whose results we were able to corroborate.

For example, the quality control employed in our project for the laboratory portion included the following:

- All test tubes were manufactured on the same day and had the same lot number;
- The same was true for all chemical reagents, radioimmunoassay kits, glass slides and stains;
- All reagents were pre-mixed by the manufacturer;
- Laboratory analysis was done in a blind fashion, using a coded identification number;
- There were daily split samples, and use of normal, high and low range standards for all tests;
- The daily data were placed on computer disks, duplicated and sent to Vienna and the USA to avoid loss or tampering.

In spite of the rigorous quality control that was employed, it was recognized that both the sample size of persons examined and the radiation relative risk would affect the power of the Project to detect adverse health effects. This use of power curves is crucial in the analysis of any epidemiological project and it has been used in some of the subsequent health studies done.

The Project was begun amid a blizzard of media claims relative to all sorts of health effects. Amazingly enough, there are still totally irresponsible claims appearing today, including a recent story of a population in a settlement which gained X ray vision as a result of the accident.

We were also aware of the much more legitimate concerns of persons living in the contaminated areas which needed to be addressed. More than five years later it is difficult to even relate the exact emotional context.

The Health Effects Team did collect extensive data in contaminated and control settlements on a number of concerns expressed by local physicians, including:

anaemia in children, thyroid size, thyroid nodules, iodine deficiency, growth of children, possible lead poisoning, and trace elements in the diet.

I will give a few examples of issues that we were able to address and bring to a closure.

The statistical data indicated that while there were some children with anaemia, there was not a difference between clean and contaminated settlements.

Lead poisoning was a concern of many parents as a result of potential emission of materials dumped on the reactor. Children in all villages had blood lead levels that were generally lower than those normally found in western Europe and the USA.

The Project also pointed out areas that could not be fully elucidated but should indicate directions for future work.

With regard to the immune system, it was clear that the overall lymphocyte levels were not affected. In the Technical Report (page 315) it was concluded that "the independent medical team remains unable to state absolutely that there are not some subtle immunological changes in the population, however, if there are such changes they appear to be of little clinical importance". Of course this referred to the year 1990.

It was also concluded that there were significant non-radiation related health disorders in both control and contaminated settlements. We concluded that between 10 and 15% of the persons examined were in need of prompt medical treatment. Hypertension and dental care were pointed out to be major public health problems.

The Health Effects Teams spent the majority of their effort on children. We were not able to find clinically obvious abnormalities that differed statistically between clean and contaminated settlements. Our foetal malformation experts examined all abortion, malformation and birth data that were supplied to us. It was concluded that there was no evidence of a significant radiation related increase in foetal malformations, but relative to most western countries, there was a high infant mortality rate.

There are a number of issues that were contained in the Technical Report that have continued to the present day.

Psychological investigation was directed by my co-leader of the Project, Dr. Lee. It was clear that up to 90% of persons living in contaminated settlements thought they had, or might have, an illness due to radiation exposure. Interestingly enough, in clean settlements the comparable percentage was 75%.

Complaints were widespread. About 80% of all persons complained of fatigue and over 40% complained of loss of appetite regardless of whether their settlement was clean or contaminated.

About 80% of persons in contaminated areas wanted to relocate and even 20% of persons in clean areas wanted to move. This is an indicator of serious psychological problems, given that essentially all of these persons had been born in these settlements and their families had been there for centuries.

The psychological issues were summarized in the Technical Report (page 359) by stating ''The psychological problems related to Chernobyl are major ... most of the people have genuine concerns and are not acting in an irrational fashion, given their circumstances''.

Obviously, there were (and still are) concerns about thyroid problems. This related primarily to thyroid enlargement, nodules and cancer. About 3% of the children were found by palpation to have enlarged thyroids and 0.5% had nodules, but there was no statistical difference between clean and contaminated areas. We did find persons with thyroid nodules. About 15% of adults had thyroid nodules, found by ultrasound. We did not find a difference between clean and contaminated settlements. Thyroid nodules increased in all groups by age of the patient.

A major portion of the Project was directed towards estimation of future health effects, particularly leukaemia and cancer.

Our review of baseline health data (such as cancer and infectious disease incidence) indicated that there was probably both under-reporting and over-reporting, and that there were huge variations in the data by year that were undoubtedly related to collection and classification problems. Cancer had been increasing each year, both before and after the accident. The rate of increase appeared to be stable.

Thyroid cancer was a major concern. In the Technical Report (page 510) we stated that "available data reviewed did not provide an adequate basis for determining whether there had been an increase in leukaemia or thyroid cancers as a consequence of the accident. The data were not detailed enough to exclude the possibility of an increase in the incidence of some tumour types".

The Health Effects Team was also asked to estimate future and lifetime health effects. Since we did not know the exact doses for each of the thousands of contaminated settlements nor the number of persons in each, we gave an example of what we felt was a representative settlement and what the expected consequences might be. We used a hypothetical settlement of 10 000 persons with a dose from external radiation of 0.1 Sv over 70 years. We predicted that thyroid cancer would almost double, that it would occur mostly in children and that leukaemia deaths in such a settlement would rise by about 50%.

In the Technical Report (page 400) we stated that ''Most of the thyroid cancers would be expected to occur in children because of their larger absorbed thyroid dose, longer lifespan, and increased sensitivity relative to adults''. We pointed out that about 80% of the persons we studied indicated that they had not taken potassium iodine as a blocking agent. We also pointed out the need for future study, stating in the Technical Report (pages 388 and 389) that ''at this point, collection and review of all the pathological slides of thyroid cancer cases that have been or are reported would be recommended'' and ''With the large release of radioiodine during the accident, it is expected that there will be a radiogenic excess of thyroid cancer cases in the decades to come. This risk relates to thyroid doses received in the first months after the accident''. We also indicated in the Technical Report (page 510) that "Reported estimates of thyroid dose in children are such that there may be a statistically detectable increase in the incidence of thyroid tumors in the future" and that "certain high risk groups (such as children with high absorbed thyroid doses) will need specific medical programmes based on their potential risks".

We did point out that, with limited resources, it would be too costly and impractical to follow all persons who were exposed and that the concept of WHO to concentrate on prospective cohort studies and high risk populations should be endorsed.

Finally, we pointed out that annual physical examinations of all exposed persons should be continued and that high risk groups would need specific programmes. We also pointed out impediments to future studies. Some of the impediments included:

— The geographic spread of exposed populations across 12 time zones;
— Pre-accident radiation exposure of some persons;
— Nationalistic and economic issues;
— Accuracy of records prior to and after the accident;
— The extremely large number of exposed persons (probably over one million);
— Finding appropriate control groups for comparison;
— Competing studies;
— Accounting for psychological issues.

In summary, I believe that the International Chernobyl Project represented a historic event. It was an unprecedented international effort, with co-operation between scientists, physicians and plain people. The findings of the Health Effects Team helped focus attention to areas of importance that we will be discussing this week.

I would also like to add that I disagree with the sub-title of this conference, " Summing Up the Consequences of the Accident". There is the implication that the issue is finished. It is clear from the data on atomic bomb survivors that any final summary of consequences from large radiation exposures of a population will take at least five decades and not just one decade to complete. I suspect that effects in children and psychological issues will remain at the forefront.

ONE DECADE AFTER CHERNOBYL: ENVIRONMENTAL IMPACT ASSESSMENT

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In November 1995, after lengthy discussions with representatives of Belarus, the Russian Federation and Ukraine, the International Atomic Energy Agency finally decided to go ahead with an environmental project, giving responsibility for its implementation to the Institut de protection et de sûreté nucléaire (IPSN) in Paris.

I do not have sufficient time to mention by name and thank all the scientists and experts who, in one form or another, participated in this project, but I cannot present it without expressing my gratitude to the members of the Project Supervision Committee, Prof. L.A. Ilyin, Ministers V. Kolosha and I. Rolevich; the co-ordinators from the three States, Minister Kenik, Dr. Poyarkov and Dr. Savkin; and M. Gustafsson, the scientific secretary of the project.

This project has a threefold objective: The first aim is to highlight the results obtained over the past ten years with a view to 'understanding' the situation in terms of decision making. The second aim is to analyse how contamination levels have changed in the various environmental media, in particular in the exclusion zone, and to study how population exposure levels have changed, in particular in the regions of Gomel in Belarus, Bryansk in the Russian Federation, and Zhitomir and Rovno in Ukraine.

The final aim is to provide an answer to the commonly asked questions: Are the populations in the zones under study living under radiologically safe conditions? Could the populations re-establish a normal life in some of the evacuated zones? Could agricultural activity be resumed in the evacuated zones? If not, when and how can a normal situation be re-established in these zones?

This project comprises four sections. The first section of the IPSN report gives a description of the present radiological situation and future developments. This section is divided into six parts describing, as clearly as possible, the level and dynamics of contamination of the soil, water, agricultural produce and forests, and the level and dynamics of the doses to the populations.

In addition to information on soil contamination, the first section contains soil contamination maps for individual States for ^{131}I as of 10 May 1986 in Belarus and in the western part of the Russian Federation, as well as contamination maps for ^{137}Cs, ^{90}Sr and plutonium.

Three conclusions can be drawn with regard to soil contamination:

— There is very pronounced heterogeneity of contamination;
— There is radionuclide accumulation in the upper 10 cm;

— The soil clearance half-lives, which fluctuate from 10 to 25 years for caesium and from 7 to 12 years for strontium according to the soil type, indicate that contamination, especially that due to caesium, will remain detectable for a very long time — from several decades to more than one hundred years, according to the contamination levels and if no intervention is called for.

Water contamination is, without doubt, one of the most interesting aspects, since results have been obtained for the entire the water cycle. Regular monitoring of water has made it possible to keep track of the levels of and changes in caesium and strontium contamination of water and sediment in the exclusion zone. These measurements show that caesium contamination is decreasing and strontium contamination is becoming stable. However, runoff may lead to the water being contaminated by the radionuclides in the soil, thereby resulting in the water activity level being up to four times as high during floods or heavy rainfall.

Interstitial water and water in the vicinity of the temporary waste storage sites established during the accident phase — of which there are some 800 with a volume of about 1 million m^3 and an activity level approaching 15 PBq — have contamination levels ranging from 1 million to 100 million Bq of strontium per litre at the storage site and from 1000 to 100 000 Bq per litre in the vicinity of certain storage zones.

Surface water, such as that of the rivers Pripyat and Dnieper, and water impoundments are slightly contaminated. The concentration of caesium and strontium contamination of the waters of the Pripyat has changed over time with reference to the average annual water intake rate of the Kiev reservoir. The average annual activity concentration attributable to caesium has been decreasing steadily since 1986 and has now reached a few tens of becquerels per litre. On the other hand, the average annual activity concentration attributable to strontium is decreasing more slowly and non-uniformly, and is stabilizing at around 1 Bq/L. The same type of development can be seen in the contamination dynamics of water impoundments of the Dnieper at Kiev, Kremenchug and Kakhovsk.

The third and fourth parts of the first section deal with the contamination characteristics of agricultural produce and forests.

The fifth and sixth parts of the first section discuss the estimated doses received by the population over three specific periods: in 1986, from 1987 to 1995, and from 1996 to 2056 (prediction).

The estimated external exposure doses received by a rural population in 1986, from 1987 to 1995 and from 1996 to 2056 in Belarus, the Russian Federation and Ukraine (expressed in μSv/kBq ^{137}Cs per m^2), have been calculated by experts from the three States. Agreement is excellent between the Russian Federation and Ukraine. The values given by Belarus are significantly higher because of the methodology used.

The external and internal exposure doses, received by a rural population in 1986, from 1987 to 1995 and from 1996 to 2056 in the Gomel region of Belarus and in the Bryansk region of the Russian Federation, have been estimated for a ^{137}Cs deposition of less than 555 kBq/m^2. The predicted effective dose for the period 1996 to 2056 is two to three times lower than the effective dose received over the past ten years. The dose due to food intake represents 60% of the total dose between 1986 and 1995. However, 80% of the dose expected to be received in the years to come will be due to external exposure and only 20% to internal exposure.

The contribution of ^{90}Sr to the internal dose is negligible at present.

Between 1986 and 1992 the committed effective dose due to internal contamination by plutonium was 25 μSv on average.

The second section of the IPSN report describes the factors affecting the normal living conditions of the populations in the three States. For each State, four aspects have been considered:

- The effect of the accident on the population's quality of life;
- The effect of the accident on agricultural and industrial development and production;
- The changes in agricultural practices due to the implementation of countermeasures;
- The necessary conditions for 'a normal life' for the population.

From the large amount of economic and social information presented in this section, four points have been developed more extensively:

(1) Public health is a major concern in the contaminated areas, since the psychological and social state of the populations living there, or of those evacuated in 1986, is characterized by great anxiety, fear about the future and a very strong feeling of hopelessness.

(2) While evacuation and relocation of the populations have reduced the exposure of the people, they have created new difficulties associated with the new living conditions and as a result of uprooting of the people from their homes. As a consequence, the demographic situation in these areas is deteriorating and the birth rate is dropping. Jobs, particularly those for the most qualified persons, are being transferred from the contaminated zones to the uncontaminated zones.

(3) There have been restrictions on the way of life of rural populations with respect to the production and consumption of foodstuffs since May 1986 in the most contaminated locations. A supply of uncontaminated products has been provided, particularly milk, but the supply of fruit, vegetables and firewood has been inadequate.

(4) Sanitary inspection of foodstuffs is continuing, but a fundamental problem is the difficulty of finding markets for the foodstuffs produced in the contaminated regions, even if they comply with the health standards. The consequence is a reduction in income of farmers and a rise in unemployment.

The third section of the IPSN report deals with the consequences of contamination on the flora and fauna of the exclusion zone.

After the acute irradiation caused in May 1986 by the passing of the radioactive plume and the deposition of radionuclides — particularly short-lived radionuclides — on the soil, the flora and fauna demonstrated considerable regenerative capacities as soon as the dose rate dropped. Nevertheless, cellular and molecular changes have been observed in animal and vegetable organisms.

Conifers have proved to be particularly sensitive to the effects of radiation. In the first two weeks after the accident, the trees received doses ranging from 80 to 100 Gy over an area of 500–600 ha. These doses led to large scale dying of pine trees and caused damage to deciduous trees. From 1988 to 1989, some of the trees in this area recovered their reproductive capabilities.

A large number of changes and modifications in the physiological and biological processes at the cellular and molecular level have been observed both in wild and domestic species. Major (potentially fatal) pathological modifications have been detected in the species most sensitive to radiation and in species whose ecological niche has been severely contaminated, including rodents and invertebrates.

The fourth section of the IPNS report describes the palliative actions taken in long-term low-dose exposure situations. It comprises three parts.

The first part deals with the evolution of the criteria associated with the countermeasures taken since 1986 in the three States, the intervention levels, and the limits on the consumption of food products. For the Russian Federation this evolution is illustrated by a move away from the dual concept of 'contamination of the environment/annual dose', applied since 1991, to the single concept of annual dose.

The second part compares the criteria of the three States with the criteria recommended by the international organizations.

The third part shows the effectiveness of the countermeasures taken, in particular in the area of agriculture; the importance and necessity of continuing the countermeasures are also discussed.

A cost–effectiveness analysis for the Republic of Belarus has been performed, for two contamination ranges, 5–15 Ci/km^2 and 15–40 Ci/km^2, giving the man-sievert cost saved as a result of applying agricultural countermeasures, namely the application of lime and fertilizers. The cost–effectiveness ratio of the countermeasures applied to the milk–meat sector is better than that of the countermeasures applied to the cereal sector.

One of the most tricky aspects of this project has been to verify the reliability of the information. Work has not yet been completed in this regard and several points remain uncertain and need to be verified.

ONE DECADE AFTER CHERNOBYL: ENVIRONMENTAL IMPACT ASSESSMENTS

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A. THE INTERNATIONAL CHERNOBYL PROJECT 1990–1991

1. INTRODUCTION

In October 1989, the Government of the former USSR formally requested the International Atomic Energy Agency (IAEA) to carry out:

> "... an international experts' assessment of the concept which the USSR has evolved to enable the population to live safely in areas affected by radioactive contamination following the Chernobyl accident, and an evaluation of the effectiveness of the steps taken in these areas to safeguard the health of the population."

The response to this request was the International Chernobyl Project, directed by the International Advisory Committee, and included the participation of the CEC, FAO, IAEA, ILO, UNSCEAR, WHO and WMO. The following five tasks defined the Project implementation:

(1) Historical portrayal of the events leading to the current radiological situation;
(2) Evaluation of the environmental contamination;
(3) Evaluation of the radiation exposure of the population;
(4) Assessment of clinical health effects from radiation exposure and evaluation of the general health situation;
(5) Evaluation of protective measures.

The Project was carried out on a completely voluntary basis by a closely co-operating team of some 200 experts, with organizations in 25 countries and 7 multinational organizations. Nearly 50 missions to the former USSR were completed between March 1990 and January 1991. Some of the findings and conclusions are presented in the following.

2. RADIATION EXPOSURE OF THE POPULATION

Independent estimates of doses to the population in the surveyed contaminated settlements were made on the basis of average deposition. It could not be assumed that such generalized dose estimation assumptions or environmental modelling calculations would accurately reflect the local soil conditions, agricultural practices and living habits in the surveyed contaminated settlements, but the results could be expected to provide a general basis for comparisons with the official USSR estimates. The dose estimates for the time period 1986–2056 were as follows:

— External dose: 60–130 mSv (6–13 rem)
— Internal dose: 20–30 mSv (2–3 rem)
— Total dose: 80–160 mSv (8–16 rem)

The Project estimates were lower than the officially reported estimates. Overall, there was agreement to within a factor of 2–3.

3. RADIATION PROTECTION MEASURES

Many factors, other than those of a strictly radiological protection nature, have had an important and possibly overriding influence on relocation policy. The need to restore public confidence, to reduce anxiety and to gain broad acceptance for the policy was found to be particularly important. Contributing factors to public anxiety were various conceptual misunderstandings and terminological problems in the process of setting intervention levels.

It appeared that due account of the many negative aspects of relocation had not been taken by the authorities in formulating the relocation policy. It was not clear that the modest nature of doses that could be averted by relocation was fully appreciated either by the population of the contaminated area or by many of those advocating a more stringent regime.

The average levels of individual lifetime dose that could be potentially averted by relocation were of the same order as or less than the doses due to an average natural background radiation.

4. CONCLUSIONS AND RECOMMENDATIONS

The major recommendations made by the Project were that more realistic and comprehensive information should be provided to the public on the levels of dose and risk consequent upon their remaining in the contaminated areas. These doses and risks should be put in perspective by comparison with the risks experienced in everyday life and risks from other environmental contaminants, for instance radon and industrial emissions.

An important conclusion was that the effectiveness of the resources allocated to the mitigation of the consequences of the accident should be compared with that of the resources allocated elsewhere to other programmes for public health improvement. Many other conclusions and recommendations were made and these are especially relevant for comparisons with the present project.

B. RECENT CHERNOBYL PROJECT 1995–1996

5. MAJOR ISSUES COVERED BY THE PROJECT

The environmental impact of the accident at the Chernobyl nuclear power plant has been subject to extensive investigations by scientists in the countries affected and by international organizations. The present Project had to be completed within a very limited time. Some of the general conclusions of the Project will be presented below. The Project covered the following five issues:

(1) Contamination situation in the affected republics;
(2) Doses to individuals living in the contaminated areas;
(3) Effect of the implemented countermeasures;
(4) Situation in the exclusion zone (30 km zone);
(5) Radiological protection criteria.

The study was based on the national reports and materials provided by the experts of the three republics and focused on the future environmental impact of the accident.

6. CONTAMINATION SITUATION IN THE AFFECTED AREAS

On 1 January 1995, the area contaminated with ^{137}Cs above 37 kBq/m^2 (1 Ci/km^2) in the three republics was 145 000 km^2, with a population of about 7 million people.

The size of the area with a surface contamination density of ^{137}Cs above 185 kBq/m^2 (5 Ci/km^2) and the number of people living in this area are significantly lower. In total, in all three republics, an area of about 30 000 km^2 has a contamination density above 185 kBq/m^2, with a population of approximately 1 million people.

As an example, the size of the area with a ^{137}Cs contamination above 185 kBq/m^2 constitutes about 8% of the territory of Belarus. The contamination is mostly determined by ^{137}Cs, although ^{90}Sr and transuranic elements are also found, mainly within the exclusion zone (30 km zone).

7. INDIVIDUAL DOSES TO MEMBERS OF THE POPULATION

The doses to people living in the contaminated territories originate from external irradiation and intake of foodstuffs contaminated with ^{137}Cs.

The average individual lifetime doses to people living in the contaminated territories are roughly distributed with one third in 1986, one third in the period 1987–1995 and one third in the period 1996–2056, as shown for the Gomel Oblast (Fig. 1). The doses are normalized to the surface contamination density, assuming that no countermeasures are applied. The ratio of internal dose to external dose depends on the soil conditions and on the contamination level and has been found to be in the range of 0.3–1.4 for all three republics.

The dose contribution from ^{90}Sr is several per cent of that from ^{137}Cs, whereas the contribution from ^{239}Pu and ^{241}Am is only a fraction of a per cent of that from ^{137}Cs.

The future individual lifetime doses to the population in the contaminated territories for the period 1996–2056 will depend on the contamination level. The total doses, i.e. the sum of external and internal doses, assuming that no countermeasures are being applied, are 5–20 mSv for the areas contaminated with ^{137}Cs in the range 185–555 kBq/m^2 (5–15 Ci/km^2), 20–50 mSv for 555–1480 kBq/m^2 (15–40 Ci/km^2) and 50–100 mSv for 1480–2960 kBq/m^2 (40–80 Ci/km^2) although higher doses can be found. These lifetime doses can be compared with the lifetime doses from an average natural background of a few hundred millisievert (Fig. 2). The lifetime doses from the natural background radiation show a substantial variation between countries. Figure 2 shows that the variation is about 400 mSv within western Europe.

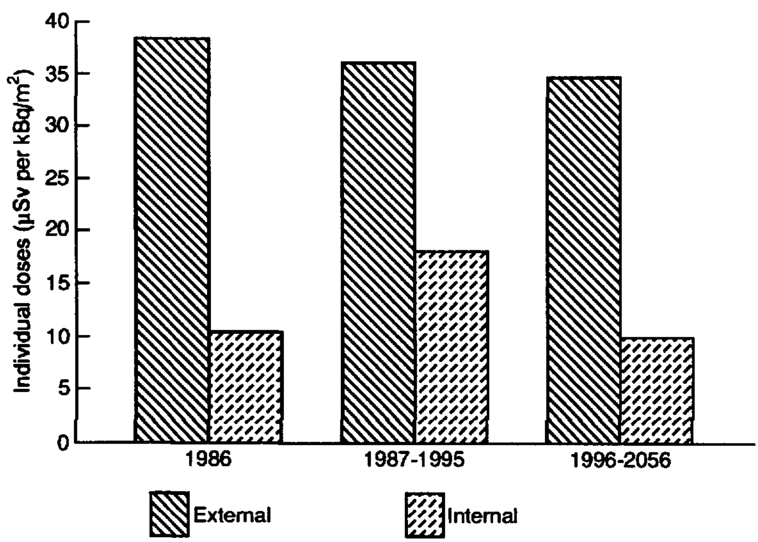

FIG. 1. External and internal doses in the Gomel Oblast without countermeasures.

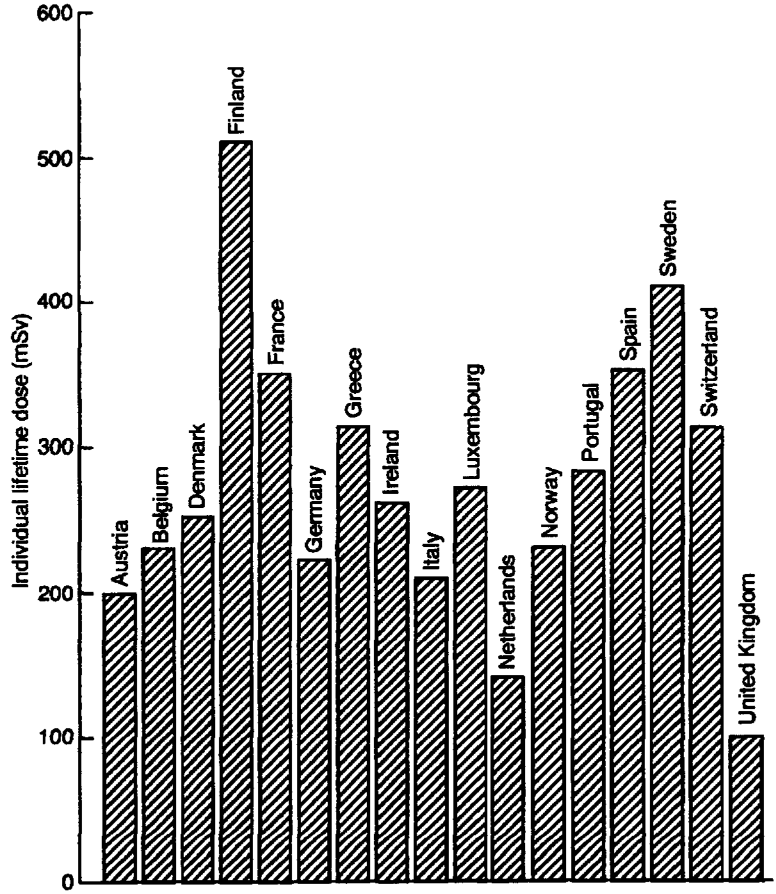

FIG. 2. Lifetime dose from natural background radiation.

8. EFFECT OF COUNTERMEASURES

Let me briefly address the programme of different agricultural countermeasures still being implemented in the three republics, as well as the relocation policy in these republics. Practice has shown that special agronomic, agrochemical and reclamation measures on contaminated agricultural lands can considerably reduce the caesium transfer to foodstuffs.

Several of these measures have a dose reduction effect of within a factor of 2–5. Some of the measures, especially those directed towards cleaning of grain crops, have a relatively high cost-effectiveness ratio, up to several hundred millions of Belarus roubles per man-sievert avoided, equivalent to about US $ 20 000 per man-sievert avoided.

In 1994, it was found that the contamination levels of agricultural products had been reduced considerably. Less than 1% of dairy products and only a few tonnes of meat exceeded the action levels.

In the three republics the intervention levels for relocation have been based on ^{137}Cs surface contamination density and annual individual effective doses. The intervention levels for compulsory relocation are 1480 kBq/m^2, and 5 and 20 mSv/a, depending on the republic.

The avertable lifetime dose at a surface contamination level of 1480–2960 kBq/m^2, corresponding to 40–80 Ci/km^2, is about 50–100 mSv as of 1996. At an intervention level of 5–20 mSv/a the avertable lifetime dose as of 1996 is about 75–300 mSv. It is here assumed that the effective environmental half-life of ^{137}Cs is 10 years. If this half-life is longer, the avertable individual lifetime dose would correspondingly be higher and vice versa with a shorter environmental half-life.

9. SITUATION IN THE EXCLUSION ZONE

The exclusion zone (30 km zone) around the Chernobyl nuclear power plant is about 2100 km^2 in Belarus, 2044 km^2 in Ukraine and 170 km^2 in Russia, and it is characterized by inhomogeneous surface contamination. In this zone, 0.5% of the pine trees perished and there were some effects on sensitive mammals. The zone is gradually being rehabilitated. The caesium contamination in hot spots is up to 370 000 kBq/m^2 (10 000 Ci/km^2). Similarly, there are ^{90}Sr hot spots of up to 185 000 kBq/m^2 (5000 Ci/km^2) and plutonium hot spots of up to 555 kBq/m^2 (15 Ci/km^2). There are, however, also areas with much lower contamination levels. The different concepts being developed in the affected republics will gradually provide rehabilitation, but this will not be implemented in the nearest future.

10. RADIOLOGICAL PROTECTION CRITERIA

During the past 10 years there has been considerable progress in the development of an intervention philosophy, internationally as well as in the three CIS republics. Although the CIS philosophy on intervention is in agreement with international guidance, the numerical CIS guidance is considerably lower than the guidance given by the ICRP and the IAEA.

The CIS intervention levels for relocation differ between the three republics. Both annual doses and surface contamination density are used at different levels. For the control of foodstuffs, the action levels for ^{137}Cs are in the range of 18.5–370 Bq/kg. For wild growing foodstuffs these levels are higher.

The individual effective lifetime dose avertable by relocation is 10–20 mSv per mSv/a for an effective environmental half-life of 10 years.

According to the international guidance for permanent relocation given by the ICRP and the IAEA and also provided in the Basic Safety Standards of six international organizations, the avertable lifetime dose is 1000 mSv. At avertable doses above this level, permanent relocation should almost always be introduced. For agricultural countermeasures the action level for ^{137}Cs is 1000 Bq/kg, which is numerically equal to the non-action level recommended by the WHO/FAO for foodstuffs moving in international trade. For restriction of foodstuffs, the action level for ^{137}Cs is significantly higher, of the order of 10 000 Bq/kg.

Several concepts and intervention levels have been used in the CIS countries over the past 10 years. Present numerical guidance in the CIS countries is much lower than the international guidance from the ICRP and the IAEA.

The above conclusions are not significantly different from those drawn in 1991, neither regarding doses and risks to people living in the contaminated areas nor regarding the effect of countermeasures.

Updating Session 2

WHO UPDATING REPORT ON THE WHO CONFERENCE ON "HEALTH CONSEQUENCES OF THE CHERNOBYL AND OTHER RADIOLOGICAL ACCIDENTS", including results of the IPHECA Programme

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INTRODUCTION

An update on WHO's activities related to Chernobyl can of course only be done in a summarizing way. The international WHO Conference on the Health Consequences of the Chernobyl and other Radiological Accidents was held in Geneva from 20 to 23 November 1995. It was the first of three international forums convened at the eve of the tenth anniversary of the Chernobyl accident. It was organized by

WHO, with the support of the Ministries of Health of three States — Belarus, the Russian Federation and Ukraine.

Major support for the Conference was provided by the Government of Switzerland, the Conseil d'état of Geneva and the Institute of Nuclear Safety and Protection of France.

I would like to underline the significance of the Conference by quoting the words of Dr. H. Nakajima, the Director General of WHO, who said at the opening ceremony: "This is the first of three international conferences related to Chernobyl and the only one devoted exclusively to health effects. It will help us to understand better the type, magnitude and severity of the observed health effects of the Chernobyl accident, and to be prepared for their future evolution".

The main purposes of the Conference were to compare the *results* of investigations related to Chernobyl and other radiological accidents, to obtain and to add new data on the type, size and severity of actual and expected health effects. In addition, there was the task to develop a modern perception of radiation effects on human health, as well as to analyse the efficiency of medical measures undertaken during and after the accident and proposals on improving them. An additional objective of the Conference was the identification of new perspective trends in basic and applied science.

The Conference includes accidents and radiation situations which have occurred worldwide since the beginning of the era of nuclear energy, and gives information on the number of participants and presentations. Some 40 countries and several international organizations and non-governmental organizations participated.

A wide range of health issues resulting from the Chernobyl accident and other radiation accidents was discussed at the Conference. Acute and delayed radiation effects (thyroid diseases, primary thyroid cancer, haemoblastosis, solid malignancies of various sites, etc.) were of high priority among the questions discussed. In addition to the plenary and main sessions there were parallel sessions, which included important subjects such as the set-up of epidemiological and other registries, techniques of epidemiological registries, techniques of epidemiological studies, estimates of individual and population doses, specificity of the health status of the population and liquidators, as well as treatment and rehabilitation of those affected. Special attention was paid to the psycho-social effects of the accident.

The Conference began with summary reports of the national co-ordinators of the International Programme on the Health Effects of the Chernobyl Accident (IPHECA) from Belarus, the Russian Federation and Ukraine. This important WHO programme was the basis for many scientific presentations and will be described later. Presentations on several national programmes followed, which were implemented in other countries as a consequence of radiation accidents. Another plenary session was devoted to basic radiobiological issues and radiation health effects. Important problems, such as social and public aspects of radiation impacts on the local population and lessons to be learned from the Chernobyl accident, were discussed at panel sessions with the involvement of majors and governors of affected cities and regions as well as the media. The closing plenary session summarized the Conference.

It is not possible here to give a detailed report on a Conference of such a size, but I will discuss significant highlights.

Acute radiation effects

The discussion of acute radiation effects (i.e. acute radiation sickness) attested to the achievements in the treatment of patients exposed to high radiation doses. Acute effects include a number of symptoms and local radiation burns. The presentations also included new treatment techniques for such effects.

The Conference considered the outcomes and the severity of symptoms in 134 accident emergency workers at Chernobyl. A high degree and a very high degree of severity of acute radiation sickness were observed in almost one third of the patients. Within the first three months, 28 patients died. During the following decade, 14 more patients died. Prior experience and urgent diagnostic measures permitted to detect the main factors during the first hours and days after the accident. They are the following: (1) determination of overall external gamma and beta radiation; (2) identification of the most severely affected group of 37 patients with possible life threatening outcomes, including 19 cases due to irreversible haematopoietic damages; and (3) start of urgent treatment measures, including transplantation of the bone marrow (13 patients) and transplantation of embryo liver cells (6 patients).

Difficulties were caused by multiple clinical syndromes such as shown in Fig. 1. Each of the syndromes could itself be the cause of death, but their combination was considered to be especially dangerous. The treatment experience gained permitted application of the principle of preventive prescription of priority measures, taking into account the possibility of development of several syndromes, as well as the potential for survival. The efficacy of this treatment of Chernobyl patients was quite satisfactory. The significant success of supporting therapy that prolongs the lifespan of the patients made it possible for the first time to raise the dose range for spontaneous recovery from haematopoiesis up to 8.0–10 Gy. This is especially important for the choice of therapeutic measures in the future.

The synthesis of broad-scale research carried out with the experience of the Chernobyl accident and other radiation catastrophes showed that people with higher doses (over 8 Gy) have a real chance to survive in the future. The presentations highlighted some of the difficulties which physicians faced when exposed patients arrived at specialized centres. The need of urgent decontamination, particularly of the skin, was emphasized. Significant acute effects were also observed and treated at the Goiaña accident in Brazil, which was discussed at the Conference.

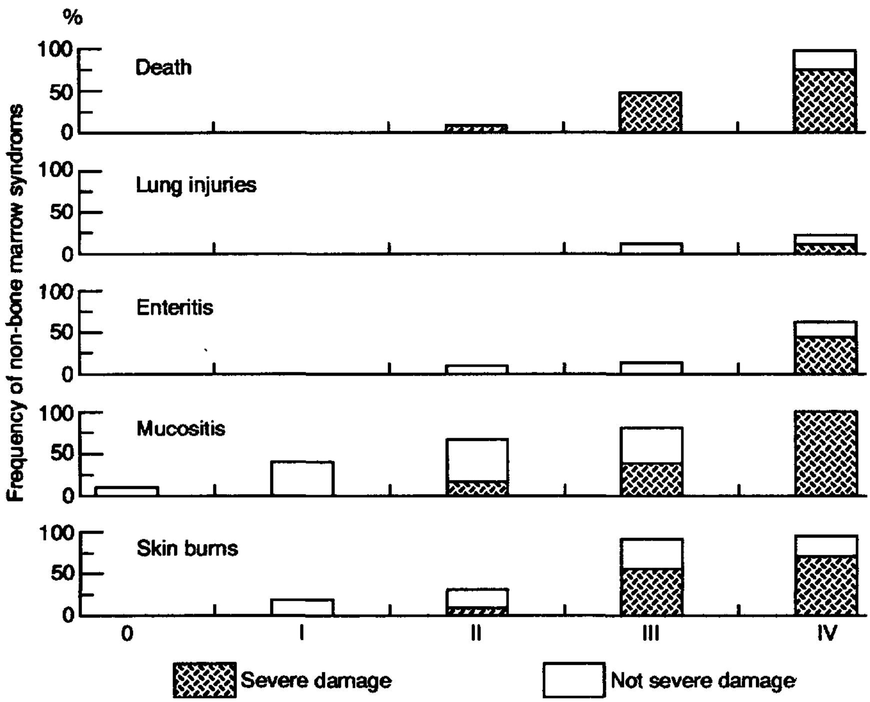

FIG. 1. Ratio of frequency of non-bone-marrow syndrome in acute radiation disease of different severeness.

A particular highlight was the experience of Professor A. Guskova who has treated over 1000 victims from accidents and emergency situations that occurred in the former USSR over 45 years. Her proposals on the necessity to strengthen international co-operation in the field of treatment and rehabilitation of the patients found wide support by the participants of the Conference.

Epidemiological registries

The good quality of an epidemiological registry is an essential element of investigating health effects and was the subject of two sessions of the Conference.

National Epidemiological Registries have been established in Belarus, the Russian Federation and Ukraine. The National Registry of the Russian Federation covers the accident effects observed in the Chernobyl, Southern Ural and Altai regions as well as those of veterans of emergency relief teams. The National Registry and the Chernobyl Registry include sub-registries (cancer, causes of death, thyroid abnormalities, haemoblastosis, etc.). They contain detailed information on the medical effects of the Chernobyl and other accidents, radiation doses for the population and liquidators, morbidity and mortality, and radioecological data. They received substantial support from the IPHECA within the framework of the pilot project Epidemiological Registry. Databases are regularly updated and serve as a reliable basis for the current and perspective survey of the epidemiological situation in the contaminated territories of the three States, as well as of the health status of the population and emergency workers. The registries are also reliable tools for decision-making in public health.

THYROID CANCER

A priority concern is thyroid diseases and was reflected correspondingly in the Conference. Thyroid diseases were the main subject of two sessions, supported by additional sessions. Details of the features of thyroid abnormalities, mainly in children, as well as aspects of prevention and treatment of malignant tumours were presented. Prof. Nagataki reported that radiation induced thyroid diseases might occur both following external irradiation and radioactive fallout containing isotopes of radioactive iodine, as well as in other radiation situations (Hanford, Techa River, etc.).

The Chernobyl accident resulted in a sharp increase in the incidence of thyroid cancer, in particular among individuals exposed to radiation in childhood and living in the radiocontaminated territories. More than 600 patients with thyroid cancer from Belarus, Russia and Ukraine were 0–14 years old at the time of the accident (Table I).

TABLE I. OVERALL AND ANNUAL NUMBER OF CASES OF THYROID CANCER DETECTED AFTER THE ACCIDENT IN THOSE WHO WHERE CHILDREN (0–14 YEARS OLD) AT THE TIME OF THE ACCIDENT

Country	Years										Overall
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	
Belarus	2	4	5	7	29	59	66	79	82	91	424
Russia	—	1	—	1	8	8	8	12	33	33	104
Ukraine	8	8	11	23	40	42	75	75	80	[a]	362[a]
Total	10	13	16	31	77	109	149	166	195	124[a]	890[a]

[a] Data to be verified.

In addition to the total number of cases of thyroid cancer, Table I gives data on the annual increase of cancer in children for the whole decade after the accident. For the first four years following the accident, 54 cases of thyroid cancer were found. The majority of them does not seem to be associated with radiation exposure. The starting point for the clinical manifestation of radiation exposure to thyroid tissue is likely to be in 1990, when 63 cases of thyroid cancer were first detected. Subsequently, a dramatic increase in morbidity was observed. A certain dependence of cancer incidence on the age of the children at the time of thyroid irradiation is noted, particularly in the critical periods of thyroid formation and functioning (Table II). It can be seen that the largest numbers of cancer occur in the age group from 0 to 4 years.

The annual medical examination of persons born in the period from 1972 to 1986 (0–14 years at the time of accident) showed that the increase in thyroid cancer was unequal in different age groups of girls and boys. A maximum growth in girls exposed at the age of 1–2 years and in boys exposed at the age of 3–4 years can be

TABLE II. NUMBERS OF THYROID CANCER IN DIFFERENT AGE GROUPS OF CHILDREN AT THE TIME OF THE ACCIDENT

Region	Number of cases			
	Total	Age groups		
		0–4 years	5–9 years	10–14 years
Bresk	97	68	27	2
Vitebsk	7	4	3	0
Gomel	225	149	72	4
Grodno	24	12	11	1
Minsk	20	14	5	1
Mogilev	21	14	6	1
Minsk City	26	17	8	1
Belarus	420	278	132	10
Per cent	100	66.2	31.4	2.4

observed. This is probably due to the higher radiosensitivity of the thyroid in girls during the first years of their life.

The effects of iodine prophylaxis following the Chernobyl accident are not clear. The fact that some part of the population of the radiocontaminated areas suffered from iodine deficiency suggests that thyroid uptake of both short lived and long lived radioiodine was quite rapid. This may be one of the causes responsible for the sharp increase in thyroid cancer in children.

Professor Williams from Cambridge University reported on his histological verification of childhood cancers at Chernobyl. In 98% of the cases his data coincided with the initial diagnosis by specialists from the affected countries. 90% of the thyroid cancers in affected children were papillary; the usual number of this histological form is 60%.

Despite the fact that different papers referred to a significant role of fission products, particularly of radioiodine incorporated by inhalation and ingestion, as well as of high doses to the thyroid (in 3700 children in Belarus the thyroid dose is over 2 Gy and in 300 children over 10 Gy), the participants of the Conference appeared to be reluctant to accept that radioiodine was the single reason for the disease. However, there was support for the necessity to re-evaluate the measures and criteria for iodine prophylaxis, particularly among younger children and pregnant women, as a countermeasure in possible radiation accidents. Estimates of radiation risks for non-cancer diseases and non-malignant thyroid tumours were also reported at the Conference. Radiation risks of non-cancer diseases of the thyroid were estimated in a cohort of 5694 children and teenagers of the Kaluga region (Russian Federation), with determined individual thyroid doses (Table III). The relative risk factor is 0.2 and the dose is 1 Gy. This value is in agreement with data published by scientists from Japan for the AHS cohort.

TABLE III. COMPARISON OF RADIATION RISK COEFFICIENTS FOR NON-CANCER DISEASES OF THE THYROID IN CHILDREN AND ADOLESCENTS OF THE KALUGA COHORT AND THE AHS COHORT

Cohort	Excess relative risk	Attributive risk
AHS (Japan)	0.3 (0.16; 0.47)	16.4 (9.1; 24.2)
Kaluga (Russia)	0.2 (0.06; 0.34)	12.1 (4.1; 18.7)

Case-control studies were used to identify the radiation risk of thyroid cancer in residents of the Bryansk region in Russia who were children and teenagers at the time of the accident (Fig. 2). The relative risk factor for thyroid cancer was shown to be 7.1 for a dose of 1 Gy. Practically the same value of relative risk was obtained by Ukrainian scientists headed by Professors I. Ljkhtarov and N. Tronko.

Radiation and epidemiological studies showed that the overwhelming number of detected cases of thyroid cancer were due to radiation exposure of the population as a result of the Chernobyl accident. The Management Committee of the IPHECA has adopted a decision in 1994 to transform the pilot project Thyroid into a long term one, to be entitled International Thyroid Project. This project is to be implemented by the WHO Regional Office for Europe (WHO/EURO).

LEUKAEMIA IN THE POPULATION

One of the basic indicators of the degree of radiation exposure is known to be a growth of leukaemias among the exposed population. Epidemiological studies after the Chernobyl accident carried out in all three States found no excessive numbers of haemoblastosis over spontaneous levels.

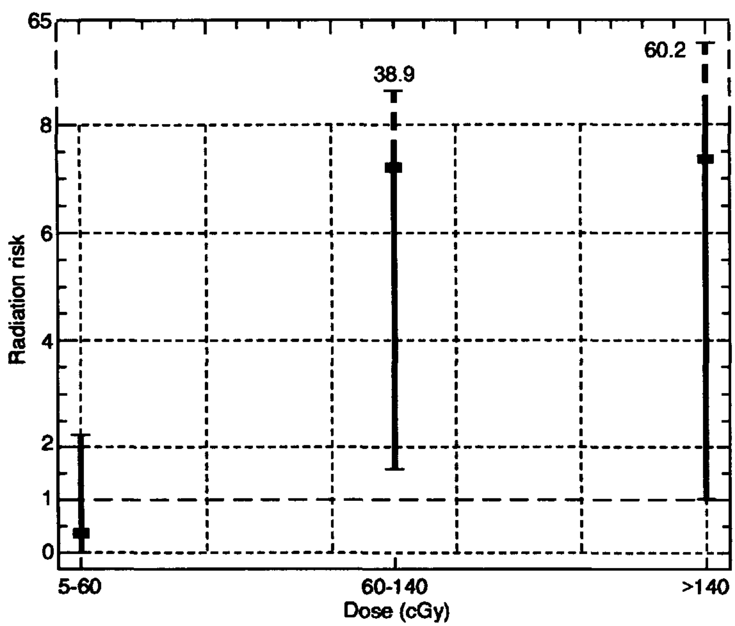

FIG. 2. Radiation risks of thyroid cancer in children and adolescents of the Bryansk region (case-control study).

A different situation occurred in inhabitants of the Techa River in the Southern Ural. A registry was set up there, covering about 29 000 persons. For cohort studies, six groups with different levels of exposure to radiation were formed. The doses for bone marrow cells ranged from 0.18 Sv to 1.64 Sv. The maximal death rate from leukaemia was observed in the most heavily irradiated group.

The incidence of malignant tumours among the population of the radiocontaminated areas in all three States shows a continuously increasing trend. However, the areas are heterogeneous as regards the development of the oncoepidemiological process. As an example, Fig. 3 gives the values of relative risks for tumours among males and females of the Bryansk region over two periods: prior to the accident (1981–1986) and after the accident (1987–1993) compared with a standardized rate for the entire Russian Federation. This figure also shows that the risks for malignant tumours are statistically insignificant compared with the common Russian rates both before and after the accident. Taking into account radiation doses to the population of the affected areas as well as the latent period of the development of solid tumours, it is necessary to organize a long term epidemiological follow-up.

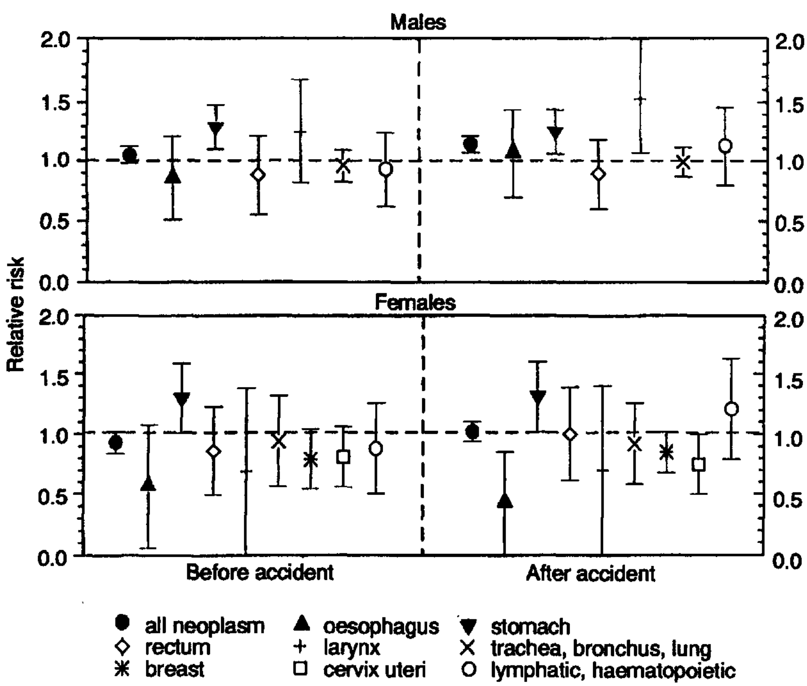

FIG. 3. Relative risk of cancer morbidity among the population of the Bryansk region.

LIQUIDATORS

A preliminary epidemiological analysis of data of the cohort of liquidators included in the final report of the IPHECA was reported at the Conference. It formed a basis for the planning and implementation of a new project for 'Accident Recovery Workers'. The project was humanitarian in nature, that is to study and to mitigate the effects of the accident on the health of the liquidators as well as to strengthen co-ordination of the activities of health care authorities in Belarus, the Russian Federation and Ukraine towards improvement of diagnosis, treatment and rehabilitation of accident recovery workers.

The issue of radiation doses to liquidators appears to be very complex. The uncertainty of the dosimetric information is very high. At the same time, the analysis of confirmed doses (registered in documents) in 119 000 liquidators indicates that the liquidators involved in 1986 and 1987 received the highest radiation doses (159 mGy and 89 mGy, respectively). These dosimetric data have been used in epidemiological studies.

It is important to note that the average age of liquidators was under 33 years at the time of working in the 30 km zone. This young cohort of people will live under a radiation risk for most of their life.

As regards a prognosis, two features should be emphasized: (1) for the first decade the attributive risk of mortality from leukaemia for liquidators has reached the highest rate (40–45%), and (2) the mortality risk for solid tumours is not higher than 5%. Attention should be paid to the fact that these prognostic estimates are in agreement with the actual data on mortality among liquidators, for the above mentioned reasons. Unfortunately, no detailed description of the results of the epidemiological study on morbidity, disability and mortality for this cohort can be given at present. However, two basic issues should be emphasized: the incidence of leukaemia and thyroid cancer in liquidators. The increase in leukaemia incidence in liquidators was two times higher than in comparable population groups. According to data of Prof. V.K. Ivanov, et al., presented at the Conference, there was a considerable increase in thyroid cancer incidence, particularly among those who worked at the accident site in May and June 1986. These new results should be the subject of further advanced co-operative epidemiological studies.

PSYCHO-SOCIAL ASPECTS

A special session of the Conference on psycho-social effects was jointly organized with UNESCO. The Chernobyl accident has taught us many lessons on public health, the most important one being the recognition of the significance of psycho-social consequences. The accident caused marked psychological distress among the population. The incidence of neurotic and psychosomatic disorders among the population of the contaminated areas has increased sharply since 1989 and up to now remains at a level which differs strongly from that in control regions. There are rather sharp alterations in relative rates of psychosomatic disorders which have no real association with changes in the radiological situation. The studies revealed an interrelation of the level of psychosomatic distress with radiation risk perception and communication. The structure of psychosomatic distress is shown by a high level of different functional syndromes, anxiety and a lower level of social functioning. All these manifestations contribute to the appearance and development of different somatic diseases. The results of radiation effects on the long term development of somatic diseases reported by Japanese scientists need further studies. This work should be significantly strengthened in future projects, since the assessment and interpretation of radiation risks regarding low doses (up to 0.5 Sv) are still contradictory.

SUMMARY OF THE CONFERENCE

The results of the Conference have led to better scientific knowledge concerning the role of radiation and non-radiation factors in health status and serve as guidelines for planning of further investigations.

In summary, the WHO Conference has fulfilled its objectives, in particular by contributing to the clarification of important issues related to health effects from the accident. The exchange of views and results from different research investigations concerning a variety of radiological events has enhanced the scientific understanding and facilitated consensus.

INTERNATIONAL PROGRAMME ON THE HEALTH EFFECTS OF THE CHERNOBYL ACCIDENT

The results of the IPHECA were the most important contribution to the WHO Conference.

During the pilot phase, the IPHECA included five pilot projects. There were also activities to support projects in the fields of dosimetry, communications and information dissemination. Study regions covered by the IPHECA in Belarus, the Russian Federation and Ukraine are identified in Table IV. Each project included the development of standardized protocols common to all three affected countries, the procurement of equipment and supplies, and professional training both locally and abroad.

In order to render material and technical support for the implementation of the pilot phase of the IPHECA, WHO purchased and supplied to the three States equipment and reagents for the necessary investigations, totalling some US $16 000 000.

TABLE IV. STUDY TERRITORIES UNDER IPHECA IN THE THREE AFFECTED AREAS

Country	Oblast	Rayon
Belarus	Gomel	Braginski, Budakoshelevski, Vetkovski, Dobrushski, Elski, Loevski, Narovlyanski, Hoynikski, Checherski, Lelchitski
	Mogilev	Byholski, Klimovichski, Kostukovichski, Kranopolski, Slavgaoradski, Cherikovski
	Vitebsk	Ushachski
Russian Federation	Bryansk	Novozybkovski, Klintsovski, Zlynkovski, Gordeevski, Krasnogorski, Klimovski
	Kaluga	Ulyanovski, Zhizdrinski, Borovski, Hvastovichi
Ukraine	Kiev	Ivankovski, Polesski
	Zhitomir	Lugninski, Narodicheski, Ovruchski
	Chernigov	Repkinski

Training courses in research and clinical institutions were arranged for 200 specialists. Scientists from the three affected States as well as international experts were involved in the development of unified project protocols to study the incidence of thyroid and blood diseases; the registration of pathologies, including cancers, and in-utero brain damage; and an oral health project (only in Belarus). For group discussions of basic programme documents, study results and co-ordination of operations, WHO organized 23 international and working group consultations. The principal management function of the IPHECA is exercised by a Management Committee.

The pilot projects in the three countries were implemented by leading research centres in the fields of radiation medicine, haematology, endocrinology and psychiatry, as well as by local health care bodies and clinical institutions. At the national level the programme was managed by national Health Ministries, national co-ordinators for the whole programme and for the separate IPHECA projects.

In addition, with a view to studying the role of the radiation factor in affecting the health status of the population of contaminated areas, work was conducted on the reconstruction of individual doses of children suffering from thyroid cancer and of patients with haemoblastosis. Dosimetric investigations were carried out and radiation risks were calculated.

The implementation of the IPHECA has rendered substantial assistance to the national health care bodies of Belarus, Russia and Ukraine in alleviating the health consequences of the Chernobyl accident. This resulted in the setup of scientific, material and technical groundworks for further medical monitoring of the residents of the radionuclide contaminated areas, as well as in-depth investigations of the health effects of the Chernobyl accident.

The principal conclusions that can be drawn on the basis of the implementation of the IPHECA pilot phase in Belarus, Russia and Ukraine are the following:

- The Chernobyl accident resulted in a sharp increase in thyroid cancer incidence, especially among the children living in the radiocontaminated areas.
- The incidence of haemoblastosis, which is closely related to radiation as an aetiological factor, has remained virtually unchanged in the post-accident period.
- Arrested mental development and deviations in behavioural and emotional reactions have been observed in a section of the children exposed in utero. The contribution of radiation to such psychological changes still remains unclear because of the absence of individual dosimetry data.
- The types and distributions of dental diseases observed in the residents of radiocontaminated areas of Belarus are virtually the same as those of the residents of uncontaminated areas. The contribution of factors other than radiation, particularly insufficient care of the oral cavity, can be more significant than radiation for the development of stomatological pathology among the population of the affected areas.
- Analysis of the data accumulated in the three States points to unfavourable trends in certain classes of diseases among the affected population and the recovery workers. However, to link these trends to the action of radiation has so far proved impossible because of insufficient dosimetric information. Nevertheless, irrespective of the aetiological factor, the increase in morbidity of the population affected by the accident requires special attention on the part of local health care bodies.
- The necessary prerequisite for conducting a scientific analysis of the radiobiological data on the effects of small radiation doses to which the population of the contaminated areas and the recovery workers were exposed is the reconstruction of individual doses in all cases of detected pathology. In the light of present knowledge, thyroid cancer and haemoblastosis have the closest connection with radiation exposure.
- The results obtained in the course of the implementation of the IPHECA pilot projects have enriched scientific knowledge concerning the effects of factors of radiation accidents on human health and serve as guidelines for planning and development of further investigations.

A comprehensive report on all pilot phase results has been prepared; the Russian version is already available and the English one is in print.

OTHER ACTIVITIES

In addition to a broad spectrum of activities throughout the WHO, related to environmental health and effects of ionizing and non-ionizing radiation, WHO/EURO and the International Agency for Research on Cancer (IARC) in Lyon carry out a number of specific additional activities in support of the mitigation and understanding of the Chernobyl accident. In some parts they are part of the IPHECA, in others they supplement it.

WHO/EURO was involved in the response to the Chernobyl accident from the outset. The psychological dimension of the Chernobyl accident was recognized early on as an important component of public health damage following the accident. An expert group meeting in Kiev in 1991 analysed and categorized the phenomenon, enabling the development of strategies to cope with future accidents and which integrate the psychological dimension into the more conventional mitigating actions. The importance, in minimizing the psycho-social dimension, of a harmonized response across Europe was also recognized and is a central theme of the Nuclear Emergency Preparedness Programme. This programme is composed of contingency planning and emergency response and is naturally linked to the WHO Radiation Emergency Medical Preparedness Network (REMPAN).

In July 1992, WHO/EURO responded to claims that there was an increase in the incidence of childhood thyroid cancer in Belarus by conducting a small mission to Minsk. This mission, in collaboration with doctors from Belarus, was to bring to the notice of the international scientific community what has turned out to be the start of a major increase in thyroid diseases that is certainly associated with the Chernobyl accident. In 1994, the International Thyroid Project (ITP) was inaugurated, in partnership with IARC, to assist Belarus in responding to the public health aspects of the epidemic. Several activities concerning improvement in diagnosis and treatment, identification of the groups most at risk, the establishment of registries to monitor the progress of the epidemic and the development of strategies to minimize the public health impact are ready for implementation.

The International Agency for Research on Cancer is a specialized agency of WHO and has been active in assisting the co-ordination of the studies on cancer risks from Chernobyl. The main activities include:

- The European Childhood Leukaemia and Lymphome Incidence Study: a study of trends in these diseases over time and by average level of radiation exposure in large geographical areas in western, northern, central and eastern Europe, including Belarus.
- A critical review of studies of cancer risk in Europe outside the former USSR after the Chernobyl accident, in collaboration with the International Union against Cancer (UICC)

— Investigations to assess the feasibility of carrying out studies of cancer risk due to radiation exposure among Chernobyl liquidators and the population exposed environmentally, in collaboration with the European Union, WHO Headquarters and WHO/EURO.
— The setting up of studies of leukaemia and non-Hodgkin's lymphoma and of thyroid cancer among liquidators in Belarus and Russia.
— The setting up of a study of factors modifying the risk of radiation induced thyroid cancer in young people in Belarus.

CONCLUSIONS

In contrast to other previous accidents, the Chernobyl accident has for the first time provided science and mankind with the unique opportunity to study in large cohorts the effects of ionizing radiation within a wide range of low doses. In order not to miss the opportunity, it is essential to continue the implementation of the IPHECA and to develop new long term projects. Their implementation should provide the possibilities:

— to improve the health status of the affected population, accident recovery workers and their offsprings by regular clinical examination as well as medical assistance, where needed;
— to assist health institutions in planning and implementation of optimal measures of step-by-step alleviation of the consequences of future radiological accidents under concrete conditions;
— to increase the theoretical knowledge on radiation risks and the real character of the dependence of stochastic effect yields on dose under low levels of exposure.

This requires additional resources which have to be mobilized for both the IPHECA and REMPAN. International organizations, governments and non-governmental organizations are encouraged to join these programmes and support them financially.

Updating Session 3

EC UPDATING REPORT ON THE "FIRST INTERNATIONAL CONFERENCE OF THE EUROPEAN UNION, BELARUS, RUSSIAN FEDERATION AND UKRAINE ON THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT", including the results of the Chernobyl programmes of the European Commission, Belarus, Russia and Ukraine

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In 1990, an agreement was reached between the IAEA and the Ministry of Atomic Power and Industry (MAPI) in the former Soviet Union to establish the Chernobyl Centre for International Research (CHECIR) at Zeleny Mys near Chernobyl. This centre was intended to provide the framework and infrastructure for all international research to be conducted in the contaminated areas around Chernobyl. At that time the European Commission was actively exploring the establishment of a collaborative research programme on the consequences of the accident with the former Soviet Union. In principle, a decision had been taken to do this within the framework of CHECIR. With the dissolution of the Soviet Union in 1991 into independent republics, the plan to implement the research under the CHECIR umbrella was no longer viable and an alternative approach had to be sought.

A pragmatic solution to the problem was ultimately found, albeit not without difficulty, given the many changes that were then taking place in each country. An agreement for international collaboration on the consequences of the Chernobyl accident between the European Commission and the ministries responsible for Chernobyl affairs in Belarus, Ukraine and the Russian Federation was finally signed on 23 June 1992. This provided the legal basis for the collaborative programme which has commonly become known and referred to as the EC/CIS Chernobyl Research Programme.

The main objective of the joint programme was to complement and assist those in the three republics responsible for evaluating and mitigating the health and environmental consequences of the accident. An important by-product was to gain an improved understanding and knowledge of the health and environmental impact of radioactive contamination and how it can be reduced; this is invaluable for the management of both the Chernobyl accident and any future accident.

The collaborative programme was intended to contribute to an improved understanding in a number of ways, not least through the synergy resulting from the integration of scientists with different backgrounds and experience. The upgrading of the local scientific infrastructure, through the provision of western technology and equipment, including training in its use, was also expected to contribute greatly to this process as well as the exchange of scientists between those institutes participating in the programme.

The scope and content of the collaborative programme can be conveniently categorized under three broad headings:

- *Assessment and mitigation of environmental contamination*
  Central to this post-accidental work is a reliable understanding of the behaviour of radioactive contamination in the environment and its transfer to man. Consequently, this aspect was given priority within the first year of the programme and five projects were launched. They dealt with various ecosystems, resuspension and decontamination strategies. In the third year of the programme, a further three projects were begun, respectively dealing with transfer of radiocontaminants to animals, radionuclide pathway analysis and the preparation of a Euopean atlas of caesium contamination.
- *Evaluation of health effects and their treatment*
  In the second year of the programme, three projects in this area were started. They considered biological dosimetry, epidemiology including dose assessment and treatment of accident victims. In the year thereafter, another three projects were initiated, two of them on childhood thyroid cancer and one on dose reconstruction.
- *Off-site management of accidents*
  Two projects in the area of off-site emergency management began in the first year, namely real-time on-line decision support systems for off-site emergency management, and a decision aiding system for the management of the post-accidental situation.

The financial resources provided by the Commission for the whole programme have amounted to about 23 MECU; taken together with the contribution from European Union (EU) institutes, participating on a cost shared basis, the total resources committed by the EU to this programme are about 35 MECU. In addition, comparable if not greater resources, at least in human terms, have been committed to the collaborative programme by Belarus, Russia and Ukraine.

Under the terms of the agreement for the programme, a co-ordination board was established with representation from the Commission and the ministries for Chernobyl affairs and the health ministries in each of the three countries. For each project approved, two scientific co-ordinators were appointed, one from an institute in the EU and the other from an institute in one of the three countries. Their main roles were to co-ordinate the overall work programme, in particular the contributions of the various partners; to manage and distribute the project resources among the participants; and to ensure that each project was completed in accordance with its specified objectives.

The radioecological research projects took into account the heterogeneity of the deposition patterns and resulting contamination levels, as well as the particularities of the ecosystems involved. The appearances of the contaminated areas were very different. They included arable land, mostly managed through collective farms, upon which full agricultural cropping was done; forested zones and meadows of semi-natural character and rainwater catchment areas feeding water into rivers and their tributaries. The patchy contamination could lead to secondary contamination through resuspension and run-off and therefore this possibility had to be assessed for the different ecosystems.

The potential for resuspension, or the transfer of deposited material from more contaminated to less contaminated areas, was thought to be a possible problem. However, this process was shown to be very slow and of little or no practical concern in the context of establishing decontamination policies and strategies. The inhalation of deposited radionuclides that are resuspended into the air by natural or man-made activities has been a matter of concern. Current exposures from this source, however, have been shown to be small in comparison with those from external radiation or consumption of foodstuffs.

The water pathway is the most important route for the long term transport of radioactive materials from highly contaminated areas to uncontaminated areas. Two main sources of long term contamination of water prevail: annual flooding and catchment transport.

Catchment transport means that water reservoirs can become a long lasting sink for contaminants through releases of radioactivity from peat bogs. The water pathway is thus a very important route for the long distance transfer of radioactivity, as happened down the 800 km cascade of the Dnieper river. However, the sediments of freshwater systems act as adsorbents and the concentration in the water will depend on the adsorption/desorption characteristics of the sediments. Nevertheless, rather high concentrations in fish have been observed in circumstances where the fish species and the local habitat were predominant parameters. The water concentrations observed definitely do not lead to life-threatening conditions of 30 million people, as was recently incorrectly reported in the Times and the New Scientist.

The radioecological half-life is longer in forests and meadows than in agricultural land, and the contamination levels are generally higher. Coniferous forests intercepted considerable amounts of radioactive material, and litter fall takes the radioelements to the soil surface. From there on the radionuclides become available for further migration to deeper soil layers and can seep through to the water table and become available for root uptake by trees. Evidence has shown that it takes up to 4 years before the radionuclides deposited on forest canopies fully enter the biogeochemical cycle of a dynamic forest ecosystem.

The interaction between caesium competitive ions added through fertilization depends very much on the soil type and soil condition. Potassium amendments can decrease the caesium uptake on poor or poorly fertilized land. Some other soil ameliorants, and processes such as the application of zeolytes, and the mulching of soil occasionally worked well under laboratory conditions but are still subject to circumstantial knowledge when applied under field conditions. However, their efficiency can now be better assessed and better quantified. Immediately after the accident, too many 'random measures' were implemented without sound statistical testing against the prevailing radioecological knowledge. It remains however true that a wealth of environmental data still needs to be evaluated.

Consumption of seasonally collected or privately grown food products is an important practice in rural areas. Food products from semi-natural zones play a major role in determining the intake of radioactivity by the rural population. These zones of extensive agricultural production are private farms, semi-natural ecosystems and forests, the herding of cattle on semi-permanent pastures and forested land, the picking of mushrooms and berries, the consumption of meat from game, and food production in private gardens. These products contribute much more to the dose than those from the better managed and tighter controlled production of collective farms.

Validated models have been developed for the assessment of external and internal exposure, taking into account parameters of social and occupational nature. The greater realism and robustness of these models enables the identification of the population groups most at risk and yields more reliable dose estimates. These models, together with the catalogue summarizing the efficiency of different decontamination techniques and outlining time and location dependent decontamination strategies, will contribute to a more efficient allocation of resources for the long term post-accidental management of the environment.

A unique atlas has been compiled of the deposition of caesium, released during the Chernobyl accident, over the landmass of Europe. The longer term radiological impact of the accident is largely determined by the level of caesium deposition and the atlas therefore provides a useful picture of the spatial variation in the impact of the accident. The atlas, which also includes many other data relevant to understanding the deposition patterns, such as meteorological conditions and topography, will be of wide interest to both the scientific and lay communities. Within the framework of the project, geographical information systems were transferred to each of the three republics to facilitate the processing and management of the underlying deposition data and the development of maps based on them. These systems will find continuing use in future for the effective management and processing of many other data relevant to the health and environmental impact of the accident.

A historical portrayal of events concerned with decisions and actions taken by the former Soviet authorities to mitigate the long term consequences of the Chernobyl accident has been compiled. This provides useful insights into the merits and disadvantages of different policy options and is useful background material for those concerned with policy development. Various computerized systems have been developed to aid decisions on how best to mitigate the consequences of the Chernobyl accident. Notwithstanding the potential of these systems for both policy development and decisions on the implementation of countermeasures, this potential remains largely unfulfilled. This failure is due to these systems not being able at present to take due account of a number of broader social considerations in addition to those of a more tangible nature such as cost and effect on health. Extensive studies were made of the social and psychological consequences of the accident and of their origins. Important lessons have been learned which, if accommodated, could improve the management of any future accident. Improving social trust and enabling individuals to exercise greater control over their own situation have been recognized as important considerations for ameliorating the situation for those continuing to live in contaminated areas.

Prior to the Joint Emergency Management Project, the development of decision support systems for off-site emergency management was proceeding independently in the respective countries and within the European Union. These disparate activities have now been fully integrated and directed towards the common development of a comprehensive decision support system, RODOS, that will be applicable throughout Europe. A pilot version of the RODOS system, applicable to the immediate and early phases of an accident, was completed in 1995 and has been installed in Belarus, Russia and Ukraine. Decisions have been taken in all three countries to integrate the RODOS system into national emergency arrangements. The pilot version will be integrated with radiation monitoring and meteorological networks and will now undergo pre-operational testing. The basis of a network of RODOS centres has been established, albeit at a pre-operational level. The fully operational network will enable a more timely and coherent response to any future accident that may affect Europe.

Health effects have been and continue to be the central issue common to all attempts to limit or to alleviate the tragic consequences of the reactor accident. In actuality, there is not a single problem, but a complex web of problems.

Five different exposure situations need to be considered:

- Several hundred persons highly exposed immediately after the accident;
- Some 800 000 emergency workers;

- About 100 000 people evacuated from Pripyat after 36 hours and later from rural parts of the the 30 km exclusion zone;
- A large population — including children — exposed to high levels of radioiodine in the early phase after the accident;
- Populations subject to continued exposure — mainly from radiocaesium — in the contaminated zones.

The first four situations involve the highest radiation exposures with no possibility of later intervention. The last situation involves the lowest exposures, but affects large populations and relates to continuing exposure.

Among the group of highly exposed persons the diagnosis of acute radiation sickness was confirmed for 134 workers. Of these, 29 died within weeks, and 14 have died since. For the latter, the incurred radiation exposures may or may not have been the cause of death.

The project on diagnosis and treatment of patients with acute radiation syndrome has yielded new insights in understanding stem cell biology and radiation sensitivity. The emergence of new drugs, and new developments in stem cell transplantation technology, have drastically changed the views of doctors on the treatment of bone marrow damage. It is unlikely that in future accident cases, allogenic bone marrow transplantation will be considered a first choice of treatment.

The liquidators are now spread all over the three republics. Large registries exist with doses that are still uncertain, but that have been partly verified, especially by the much improved EPR dosimetry, while the fish biodosimetry is still encountering problems. An epidemiological pilot study for the follow-up of the liquidators has been successful, but it has shown that it is a difficult and expensive task. Increased mortality rates are found for violent causes, including suicide, a symptom of the disruptive indirect effects of the accident. Leukaemia may be increased among the liquidators with higher doses. It will be necessary, however, to compile descriptions of the interventions carried out by the liquidators, with dose estimates and numbers of persons involved, before definite conclusions can be drawn.

It appears to be equally difficult to follow the health status of the early evacuees. Among them, one might also see an increase of leukaemia — especially in the children — if a thorough study were possible. It remains very important to follow the children who were prenatally exposed. A number of 1500 of such children has been mentioned, but not yet confirmed. If feasible, it would be very important to follow these children, not only for leukaemia, but also for damage to the central nervous system.

In December 1991, on the occasion of a workshop at the Gesellschaft für Strahlen- und Umweltforschung (GSF) at Munich, Germany, a first report was given concerning an alarming increase of childhood thyroid cancer in Belarus, and somewhat later in northern Ukraine. In January 1992, the European Commission established a panel of internationally recognized thyroid experts together with invited observers from other organizations. The necessary arrangements were made for organizing a fact finding mission which took place in October 1992. The report of the panel was published in January 1993, and contained strong recommendations for research and assistance. The European Commission reacted promptly on five levels: research — co-operation — training — equipment — drugs. In this undertaking the European Commission has strived towards an internationally co-ordinated approach. Unfortunately, this broad-scale approach made by the European Commission has not always received the recognition it deserves, and the very same can be said of the assistance provided by the Japanese Sasakawa Memorial Health Foundation. Up to now, nearly 900 cases of childhood thyroid cancer have occurred, three of the children have died and, most sadly, the number of deaths will increase.

Support for research projects on diagnosis and treatment was provided by the Radiation Protection Research Action, humanitarian aid was provided by the European Community Humanitarian Office (ECHO), including necessary equipment for diagnosis and treatment, as well as drugs for the long term treatment after thyroid surgery. I am pleased to be able to assure our Conference President, Minister Merkel, that the European Commission, through ECHO, has provided the necessary drugs for the treatment of the patients. In addition, through the technical assistance programme for the CIS (TACIS) a large training programme for 80 specialists was launched, as well as designing and installing facilities for forming and packaging L-thyroxine tablets in the Chernobyl affected regions, and defining and implementing measures to improve the production, packaging, storage and distribution of iodized table salt in the iodine deficient regions.

The possible health effects of the continued exposure in the contaminated zones remain a central concern and also a central point of disagreement. It is understandable that a population who has not been fully informed for several years after the accident will now refuse to believe official statements and, instead, will feel that all kinds of illness that are now being diagnosed must be due to radiation. This misperception of radiation risks and the resulting distress are extremely damaging to the people. It is, therefore, of greatest importance to arrive at a realistic perception of radiation risks, since otherwise remedial actions are due to fail.

Within the epidemiological project, trends of cancer incidence before and after the reactor accident and inside and outside the contaminated zones of Ukraine have been determined. A very important finding is that ten years after the accident there is no observable effect of protracted exposure. The Institute of Haematology in Minsk obtained the same result — with good regional data — for childhood leukaemia in Belarus. The lack of an observable increase of leukaemia in children which is a prime indicator of radiation effects has wider implications; it makes it unlikely that other increases of morbidity can be due to radiation. The thyroid tumours due to the high initial exposures are, of course, an exception. The studies on the health consequences have shown that only the large increase of thyroid cancers is at present attributable to the accident.

Much has been achieved over the past four years of collaborative R&D and significant advances have been made in understanding the environmental behaviour of long lived radionuclides, in the development of decontamination strategies, in emergency preparedness and management, and in diagnosis and treatment of acute and delayed health effects. Much, however, remains to be done in several areas. This embraces the recognition and amelioration of health effects, the restoration of severely contaminated territories, the emergency management procedures, the data collection, quality assurance and data management, and the restoration of confidence of populations living in contaminated regions. These are the priorities of the current R&D framework programme of the European Commission. Together with the Member States of the European Union and the republics concerned we trust that the coming years will consolidate the success of the first phase of this collaboration.

During this first phase, an efficiently operating communication and consultative network has been developed. The European Commission plans to use this network and particularly the national secretariats in Belarus, Russia and Ukraine for continuing this most rewarding scientific collaboration. The Commission favours an integrated international approach and is prepared to share the use of this network for dedicated co-operation with other organizations for the benefit of the people that are suffering from the consequences of the Chernobyl accident.

CONCLUSIONS

1. There has been considerable progress in the understanding of the environmental behaviour of long lived radionuclides. This illustrates that good science allows for well substantiated decisions on socially acceptable living conditions.
2. A wide variety of remedial measures has been critically evaluated with respect to their effectiveness, their large scale useability, and their agricultural and ecological side-effects. In most food products, the radiocaesium concentration is well below the intervention level, though semi-natural products and farm produced milk and foodstuffs remain a problem.
3. Hardware and software for implementing compatible decision support systems for off-site emergency management throughout Europe were transferred to the three republics.
4. The establishment of an emergency management network of RODOS centres will contribute to a more coherent and consistent response to any potential future accident.
5. The increasing incidence of thyroid cancer will require major resources. The pre-conditions for a continued successful co-operation exist in the substantiation of the diagnosis, in the established classification and identification of subtypes, in the cytochemical and molecular biological investigations, and in the adoption of treatment protocols by all centres.

6. The fact that an increase in laukaemia incidence has not yet been observed does not exclude the possibility that there are certain increases below the threshold of statistical observation.
7. The consequences of this reactor accident were and continue to be enormous and much further work and more international collaboration and assistance will be necessary to derive the benefits from all the lessons that can be learned.

BRIEFING SEMINAR

Keynote Presentations

Moderator

G. WEBB
IAEA

KEYNOTE PRESENTATION

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It is an honour for me to address this international conference, sponsored by the European Commission, the IAEA and WHO, to sum up the consequences of the Chernobyl accident, ten years ago. As Chairman of the Steering Committee of the UNESCO Chernobyl Programme, I have been to the contaminated territories of Belarus, Ukraine and Russia, and saw the extent of the catastrophe. I am glad that UNESCO has joined other agencies in contributing to mitigating the consequences of this accident.

Among the numerous natural and man-made disasters which have required large scale international assistance over the last ten years, the Chernobyl catastrophe has been perceived and remains synonymous of a disaster of historical dimensions both for the media and in the mind of a large part of the world population. Other disasters are usually traced to natural, political and ethnic causes, as well as technological ones. They tend to occur over a short period of time and their direct effects are relatively short lived. Chernobyl is, however, of a different nature:

(1) Radiation and its consequences cannot be seen and dealt with directly;
(2) Even though the land looks pristine and perfectly normal, large parts of it will remain contaminated for decades and most of the evacuated population knows it may never return 'home';
(3) The number of cancers have risen significantly, especially among children,
(4) Based on this situation, the psychological and social consequences of this catastrophe are becoming some of the main sources of hardship, in particular for the populations still living in the contaminated areas;
(5) Finally, the economic difficulties and the major political and social reforms being implemented in the three most affected countries are complicating, for the time being, the condition of Chernobyl victims.

Chernobyl is therefore, de facto, the worst possible example of uncontrolled scientific and technological 'progress', and the fact that it was a nuclear accident made it all the more dramatic for the population and the mass media.

In 1990, the Director-General of UNESCO responded to the call made by the Republic of Belarus, Ukraine and the Russian Federation, and mobilized the Organization to prepare the UNESCO Chernobyl Programme Framework Agreement, which he signed in early 1991. The organization has, ever since, worked in close co-operation with national authorities and other international agencies in the context of the Interagency Task Force of the United Nations.

The initial objective of this Programme has been to carry out immediate relief actions with concrete, visible results for the population of the contaminated areas by answering some of their priority. The nine community development centres created with the assistance of UNESCO are now operating to help the population with the social and psychological consequences of the accident and, today, the full range of activities include some 30 projects, completed or under way. A progress report on the Programme is available and a small exhibition is presented.

Another important objective of UNESCO in the initial stages of its Programme has been to raise awareness about the accident and its consequences, with the assistance of several of its goodwill ambassadors, and to mobilize the financial support and energies of individuals and institutions around its projects.

UNESCO has also been keen to foster international scientific research on the consequences of the accident. It was our view since the inception of the Chernobyl Programme that, while the first priority should be to support materially and psychologically the population, the second goal should be to encourage scientific research. Indeed, we owe it to future generations to learn as much as possible from this catastrophe.

UNESCO's attitude was, therefore, to develop its action in fields where it has specific competence and resources to contribute to the Programme, such as in hydrology, in marine sciences and in the ecological sciences, and to work closely in these areas with other United Nations agencies and the European Union.

However, I regret to say that the work in this area has been carried out by a small number of institutions, while UNESCO's contribution has remained minimal despite some good contributions and initiatives; several projects in hydrology, for example, prepared by the International Hydrological Programme in the above mentioned context, have not been funded even though they had been jointly planned and considered important.

Moreover, UNESCO, has been supporting the work of the academies of sciences of the most affected countries with the limited funds available from its regular budget and will also support the development of scientific laboratory facilities within the 30 km zone at the request of Ukraine.

Research activities have been more important in the field of social sciences and, in particular, in education, psychology and sociology, where UNESCO has been active, in part using the nine community centres created in the three countries as a basis for its work.

One of the problems which was quickly identified when the Chernobyl Programme of UNESCO was designed was the lack of trust of the population in official information and the dramatic impacts this had on their psychological state and on the programmes designed to cope with the consequences of the accident.

The absence of any information for days after the accident only fuelled rumours, induced fear and discredited decision-makers, whether they were public officials or professional specialists.

Despite the important efforts of the national authorities ever since to regain the indispensable trust of the population, much remains to be done; and national financial resources are notably insufficient to cope efficiently with the problem of information as it exists.

We should also accept the idea that we may not have always provided the international community and the media with the sharp, understandable picture on the Chernobyl situation as could have been expected.

UNESCO itself has fallen in this trap recently when a book of its MAB Series on The Ecology of the Chernobyl Catastrophe presented an overall picture on Chernobyl using a wide range of statistics, some of it unauthenticated or not corroborated despite the peer review carried out by the publisher. The biased use of this information by some media has raised questions in recent weeks. This is why UNESCO, which stands for rigour in scientific research, has decided to withdraw this book from circulation until an audit has been completed by high level peer review.

Turning now to more future oriented preoccupations, the Chernobyl accident has taken a heavy toll of suffering in Belarus, the Russian Federation and Ukraine, and warrants a reflection that is both global and free, in which the world can engage, in view of its ethical, international and transborder aspects.

Social upheavals and the need to monitor the extraordinary achievements of technologies in a harmonious way are making ethical issues appear larger and larger. Much of this questioning touches on areas relating to UNESCO's competence. Who should determine the priorities and choices of technologies and on the basis of which social goals? How can we define democratically the risks which can be considered as 'acceptable'? What is the level of responsibility and solidarity which can be expected from individuals and groups in relation to both present and future generations?

The answers to such questions go beyond the narrow confines of professional practice and national borders. In a multipolar world of an unprecedented splintering of perceptions, it is more than ever necessary to work for the emergence of values which would make common existence viable technologically, ecologically and socially.

Such an ethical reflection calls for an exchange of experience and ideas, in complete freedom, among decision-makers, eminent specialists, representatives of professional groups and leading figures of the civil society, in all its diversity, in order to identify the issues and set the agenda for future generations.

More generally, there is a need for education and information of the public at large, and in particular the populations more directly concerned. A public debate, with the participation of all actors concerned, including communicators, can only enhance a democratic process that is very much needed in this crucial area. An appropriate communication can only be based on the accuracy of information, including uncertainties when they exist, as well as on a concerted effort on education.

It is in this context that the national authorities of the three most concerned countries and UNESCO have launched two rather large projects.

The first project was initiated more than a year ago, to deal with the information of the public of our community development centres, with the financial support of Canada and the Netherlands, and the participation of the French Institut de protection et de sûreté nucléaire (IPSN). The project seeks to plan, conceive, produce and disseminate information in a form which, we hope, will contribute to resolve some of the problems in the contaminated area. UNESCO will soon invite leading specialized institutions to co-operate in this project.

The second project deals with the development of a general purpose international pedagogical kit on Energy, Development and the Environment (EDEN) for 12–17 year old students to learn about key concepts in this area and to define and adopt more environmentally conscious lifestyles. This kit should be ready in a few months.

Chernobyl is not over. Everybody agrees with this statement. We need to pursue our efforts. A co-ordination of activities is, however, more than ever needed to integrate the projects under way or planned among themselves and into the long term development of the contaminated area. The experience we have gained in working with other international agencies is encouraging. And we look to the interagency task force to continue its mission and to the donor community to continue funding the projects under way and planned.

The excellent and close working relations developed with the national, regional and local authorities involved with our projects represent a further basis for such co-ordination. We hope to strengthen even more this co-operation in the future and will continue to make UNESCO centres and networks available to our partners, NGOs and other United Nations agencies for the implementation of Chernobyl projects.

But as we assess the consequences of the Chernobyl accident and review the progress made in coping with its massive consequences, I would like to note that Chernobyl has also been a bridge for East–West scientific co-operation. I hope this co-operation will be strengthened so that we can learn more, for the generations to come, on the effects of such a dramatic accident on the natural and social environment.

ASSESSMENT BY UNSCEAR OF WORLDWIDE DOSES FROM THE CHERNOBYL ACCIDENT

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1. INTRODUCTION

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established 41 years ago in 1955 to advise the General Assembly and thereby all countries of the world of the sources and effects of ionizing radiation. The initial work of the Committee involved primarily an assessment of exposures worldwide from the testing of nuclear weapons in the atmosphere as well as a review of the biological effects of radiation. Over the years, the Committee has published a series of comprehensive reports that have systematically evaluated the exposures from natural background radiation, the various practices or events that have resulted in releases of radioactive materials to the environment, medical and occupational radiation exposures, the results of epidemiological studies of radiation effects, the genetic effects of radiation and the basic physics and biology of radiation interactions and responses. The Committee has achieved a high reputation for the scientific quality of its reports. They serve as reference documents for radiation scientists throughout the world. The Committee has been priviledged to review and document a field of science that has received a great deal of attention. No other genotoxic substance or agent has been studied as extensively as ionizing radiation. Sensitive detection methods are available to trace the dispersion and behaviour of radionuclides in the environment and their transfer to humans, and a great deal of knowledge has been acquired on radiation effects. It is on this background of experience and knowledge that the Chernobyl accident occurred in 1986.

2. FEATURES OF THE ACCIDENT AND THE DOSE ASSESSMENT

The Chernobyl accident caused enhanced radiation levels throughout Europe and measurable, trace levels everywhere in the northern hemisphere. Because of the concerns that arose at the time and because of the many measurements that were made, UNSCEAR decided to undertake a detailed assessment of the collective dose from the accident. The evaluation served to develop the methods of dose estimation for this type of radiation source and to improve the comparability of results among countries. The results of the analysis were published in the UNSCEAR 1988 Report.

The previous experience of evaluating the impact of radionuclides released to the environment was derived from the monitoring of fallout radionuclides produced in atmospheric nuclear testing. The atmospheric tests took place mainly from 1951 to 1962, but a few additional tests were conducted until 1980. The atmospheric tests resulted in substantial free release of radionuclides directly into the atmosphere. That practice was a Chernobyl accident in its own right. In fact, the amount of ^{137}Cs released in atmospheric testing of nuclear weapons was over ten times that released in the Chernobyl accident. The deposition per unit area in central Europe was about the same from fallout summed over the several years and from Chernobyl occurring in the single year 1986. Much of the debris from nuclear tests, especially from the high-yield explosions, was injected into the stratosphere, from where more widespread dispersion and relatively uniform deposition occurred. Enhanced levels of fallout occurred in the northern hemisphere, where most of the testing took place, and in the mid-latitude region, because of the nature of the stratosphere–troposphere exchange. Figure 1 shows the annual deposition of ^{137}Cs in the mid-latitude band of the northern hemisphere. The fallout deposition occurred throughout the period of testing and for several years after 1980 until the stratospheric inventory was depleted. Also shown is the average regional ^{137}Cs deposition in east-central Europe. There were local areas in Europe where the deposition was 10 times greater

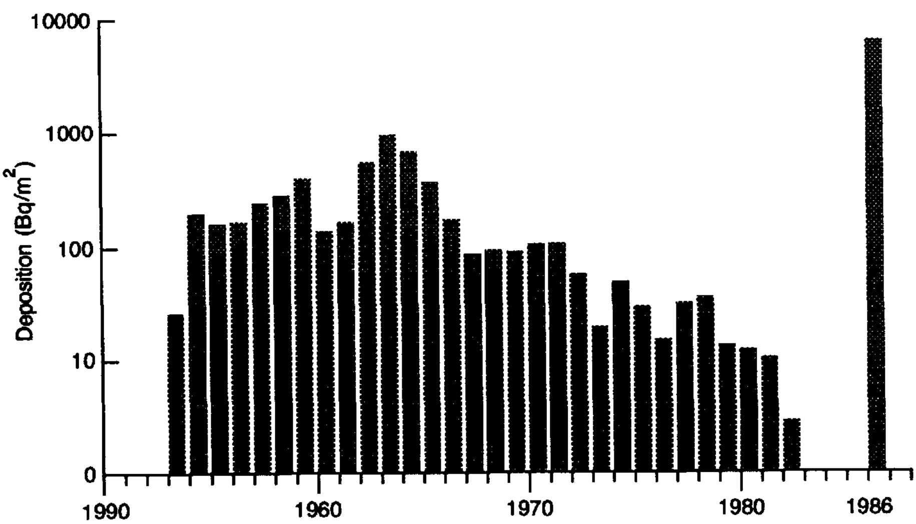

FIG. 1. Deposition of ^{137}Cs in east-central Europe from atmospheric nuclear testing (1953–1982) and from the Chernobyl accident (1986).

than this, and in areas surrounding the Chernobyl reactor the deposition was 100 times greater or more.

Many different radionuclides were produced in weapons testing. Because of the delayed deposition from high altitudes, some of the prominence of short lived radionuclides was reduced by radioactive decay. Much was learned of the behaviour of radionuclides in the environment, and these substances served as environmental tracers for the study of meteorological and hydrological cycling of elements. The behaviour of caesium was, in fact, largely rediscovered after the Chernobyl accident. There is perhaps general unawareness or else forgetting the significance of exposures to the world population from atmospheric weapons testing. The limited test-ban treaty and the cessation of atmospheric testing by all nations put an end to this unneeded radiation exposure. I am mentioning this information on fallout to remind you that we have been here before. The greatest global release of radionuclides from a man-made source was atmospheric testing of nuclear weapons. The greatest local impact of man-made releases was, however, the Chernobyl accident.

Other comparisons are being made with the Chernobyl accident. It is said that the Chernobyl accident was a disaster 200 times greater than that of Hiroshima and Nagasaki combined; this refers only to the release of radioactive materials. Actually, these were entirely different events. Chernobyl was a thermal and steam explosion that released fission products accumulated in the reactor core. The Hiroshima and Nagasaki bombs were nuclear explosions that caused a great deal of direct radiation, thermal and blast effects that devastated large urban areas. There was little production of fallout radionuclides in the Hiroshima and Nagasaki explosions; a comparison only on this basis is thus entirely misleading. There are many other comparisons that could be made. Bhopal was a technological accident in which the toxic substance released caused immediate deaths and injuries to thousands of people. Earthquakes, floods and wars are natural and man-made events that cause disruption of societies, evacuations and economic losses. More directly comparable to Chernobyl was the Three Mile Island reactor accident in the United States of America in 1979. This caused equal devastation of the reactor core. The containment building, however, prevented the release of all but minimal amounts of radionuclides from the Three Mile Island reactor, showing that safety systems can prevent a nuclear accident from becoming a major catastrophe. Each event is unique in its own way. Chernobyl was a disaster of incomparable magnitude. It does not need to be misrepresented or sensationalized. We scientists must be extremely careful and accurate in our analyses and statements. We have a duty, as well, to clarify and correct, if need be, misdirected or misleading statements, claims and comments that will be made by politicians and the media, and that, if not countered, will be a disservice to individuals and to society.

There were several unique features of the Chernobyl accident that differed from our previous experience of measurement of radionuclides in the environment. The contamination from the Chernobyl accident arose from a single surface location. This meant that iodine and short-lived radionuclides were prominent in the first days and weeks following the accident. The winds shifted in various directions during the ten-day period of active release of radionuclides, and rainfall occurred sporadically in various areas. The deposition of radionuclides was, therefore, non-uniform. This necessitated more detailed measurements and required that subregions of countries be considered in the dose evaluation.

The assessment performed by UNSCEAR of exposures from the Chernobyl accident relied on measurements made in countries during the first year after the accident. Sufficient results were available to evaluate the first-year exposures in 34 countries. These included almost all countries of Europe, the USSR, and a few countries in Asia and North America. Country-wide, average results were considered in general, however, for several countries in Europe, and exposures were evaluated in two to four subregions to avoid averaging more wide-ranging dosimetric data.

The exposure evaluation concentrated on the major radionuclides released and the dominant dose pathways. The accident was largely an iodine and caesium release. Of course, some short-lived radionuclides were important in the first weeks in contributing to external exposures, and ^{103}Ru and ^{106}Ru could be accounted for in the first year, but the effective dose and the absorbed dose to the thyroid were mainly due to ^{131}I, ^{134}Cs and ^{137}Cs. The dominant pathways were external irradiation from deposited radioactive materials (primarily ^{137}Cs in the longer term) and dietary ingestion of radionuclides (^{131}I in milk and leafy vegetables during the first month and, after that, ^{134}Cs and ^{137}Cs in foods). Two secondary pathways were also evaluated from data generally available. These were external irradiation from radioactive materials present during cloud passage and inhalation of radionuclides in air.

The estimates of first-year doses reflected the prevailing conditions in countries, with measured values reflecting the protective measures taken. Estimates were made of the effective dose received during the first year and subsequently, and of the first-year absorbed dose to the thyroid of adults and one year old infants.

Contributions to doses beyond the first year resulting from deposited radioactive materials were estimated from models derived by UNSCEAR from fallout measurement experience. For the most cases, these involve multiplication of first-year integrated deposition or concentrations in foods by suitable dose factors (e.g. dose per unit intake) and intake rates (e.g. food consumption rates, breathing rates). The projected dose after one year from external irradiation was computed from cumulative deposition, multiplied by dose factors assuming a radionuclide distribution in soil, with account taken of radioactive decay, building shielding and indoor/outdoor occupancy. Uniform values of the building shielding factor (0.2) and the indoor occupancy factor (0.8) were used. The observed reductions in exposure levels in urban areas as a result of runoff was also incorporated in the dose models; a fractional amount (0.5) of deposition was assumed fixed on urban surfaces and the remainder lost in short-term runoff.

Five basic food groups were considered in evaluation of the ingestion pathway: milk and milk products, grain products, leafy vegetables, vegetables and fruit, and meat. Individual foods were weighted according to consumption amounts to determine average values of integrated concentrations for each food category. Food consumption statistics reported from individual countries were used in evaluations of doses to adults. For infants, consumption estimates vary widely owing to differing definitions of the representative age; therefore, standard values of consumption rates of foods by infants were adopted for use in all countries.

3. FIRST-YEAR DOSE RESULTS

Estimates of average first-year effective doses based on measurement results available from the countries ranged from very low to just above 0.7 mSv. The results are shown in Fig. 2. The highest values were estimated for countries in south-eastern,

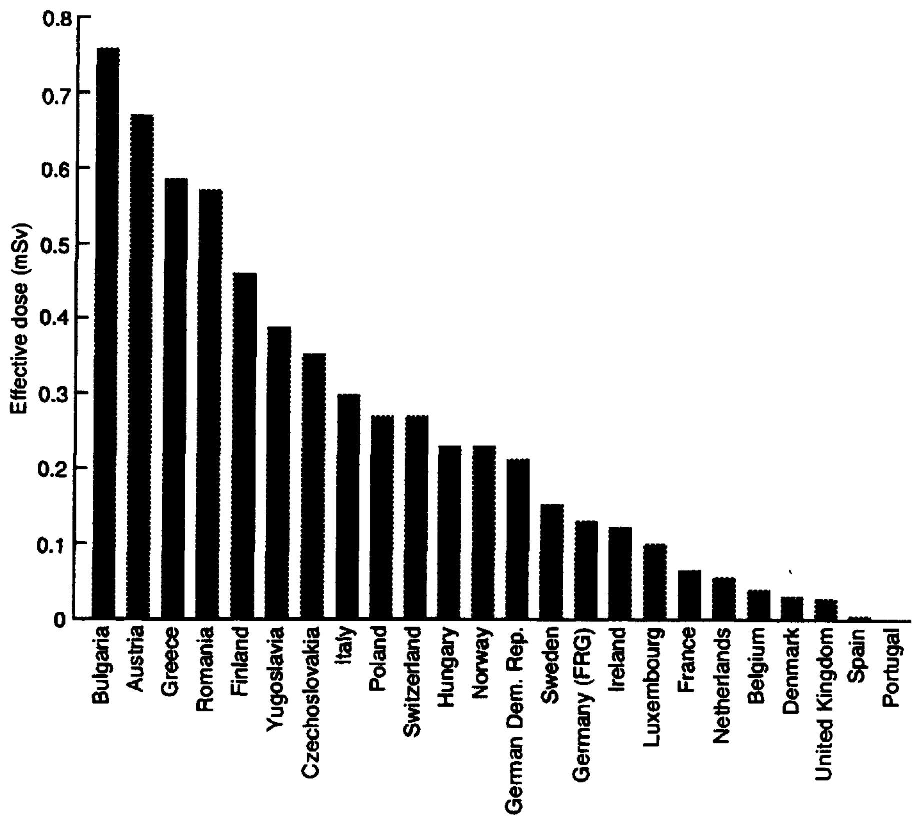

FIG. 2. First-year effective dose in European countries from the Chernobyl accident.

central and northern Europe, followed by other countries at greater distances from the accident site. The highest country-average result (0.76 mSv in Bulgaria) is about one third of the natural background annual dose (2.4 mSv). The comparison of the doses including natural background exposures shows that the doses from the Chernobyl accident are well within the normal variations in the natural background dose. These results, shown in Fig. 3, are given in the same order of countries as in Fig. 2. In subregions of Romania and Switzerland the effective dose equivalents in the first year were in the range of 1 to 2 mSv, and in the Byelorussian Soviet Socialist Republic it was 2 mSv, which is comparable to the dose received from the natural radiation background. Even these subregional results are for broader regions of countries, and therefore some higher values (and also lower values) could be expected for more narrowly defined areas or particular groups of individuals. The most unusual or extreme doses to individuals were not evaluated by UNSCEAR, since the main purpose was to evaluate the collective doses, which could be based on representative or average results.

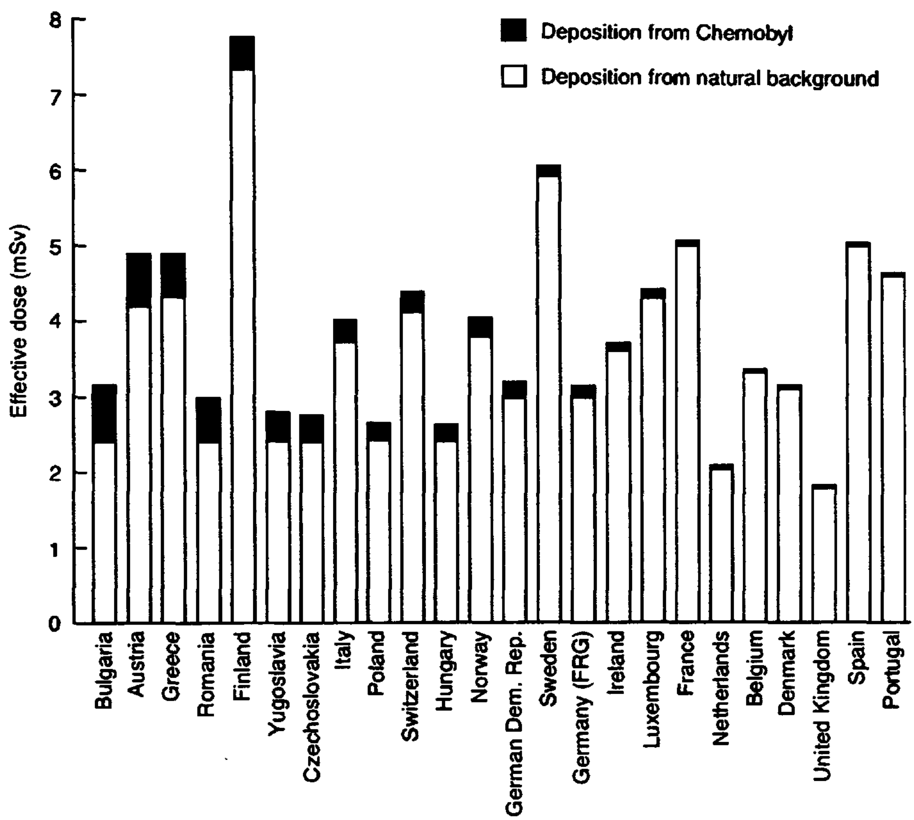

FIG. 3. First-year effective dose in European countries from the Chernobyl accident including natural background exposure.

In addition to effective doses, the absorbed doses to the thyroid of infants and adults were estimated. These were not of great significance in countries outside the former Soviet Union. The results are given in the UNSCEAR 1988 Report.

4. TRANSFER FACTORS

The measurement results reported and available for the 34 countries, for which first-year doses were evaluated, provided a pattern of transfer of radionuclides in air, deposition and diet to dose which could then be used to evaluate the doses in all other countries of the northern hemisphere. Transfer factors were evaluated for the major radionuclides contributing to dose: ^{131}I, ^{134}Cs and ^{137}Cs in all pathways and several short-lived emitters in the external irradiation pathway in the first month, and ^{103}Ru and ^{106}Ru in the first year after the accident. The relative proportions of these radionuclides in air and deposition showed some variability at particular times of measurements, but there were no significant differences in the ratios of integrated values at various locations. With the use of these ratios, all transfer factors could be referred to ^{137}Cs deposition and could be combined into a single overall transfer factor.

For external irradiation, the same assumptions and transfer factors applied to all regions. For the ingestion pathway, however, a latitudinal dependence in the transfer factor was evident. Higher values of transfer factors were derived for locations at lower latitude where agricultural conditions were more advanced. At northern latitudes the growing season had not yet begun at the time of the accident, and cows were not yet on pasture. The lowest values of transfer factors from deposition to foods were derived in these regions. Three separate geographic regions were specified to define general values of transfer factors: southern ($<41°$ latitude), temperate (41–55°) and northern ($>55°$).

The values of the transfer factors (average for the temperate region) are given in the following listing. These are average effective doses per unit ^{137}Cs from the Chernobyl accident. They show that the lifetime external exposure is approximately

Exposure pathway	Normalized effective dose (μSv per kBq/m^2)	
	First year	Total
External exposure	10	86
Internal exposure	44	76
Total	54	162

8 times the first-year external exposure. Just over half the lifetime internal exposure is received in the first year following the accident. The lifetime total exposure is about 3 times the first-year total exposure. The transfer factors are used to obtain the doses from all radionuclides, but they are applied to the deposition of ^{137}Cs only. To this extent, they reflect the particular composition of radionuclides in the material released from the Chernobyl reactor. They also refer to the agricultural conditions prevailing at the time of the accident. These values would be generally valid for comparable types of radiation sources, but they are of specific use to evaluate doses from the Chernobyl release where only an estimate of ^{137}Cs deposition can be made.

5. CAESIUM-137 DEPOSITION IN THE NORTHERN HEMISPHERE

A general decrease of radionuclide deposition with distance from the release site can be expected, with variability due to wind and rainfall differences. In the case of the Chernobyl accident, the release continued for ten days while the wind changed to all directions. Therefore, some variability was averaged out and a relatively uniform decrease in ^{137}Cs deposition with distance from Chernobyl was observed.

From the log-log plot of average ^{137}Cs deposition in the countries outside the USSR reporting measurements with distances from the accident site, an approximate deposition–distance relationship was determined. This ranged from about 10 kBq/m^2 of ^{137}Cs deposition density at 1000 km to about 0.01 kBq/m^2 at 10 000 km. With this relationship, ^{137}Cs deposition was estimated in all regions of the northern hemisphere where measurements were not available. The distances to particular regions were population-weighted averages of the distances to the capital cities or the approximate population centres of the countries of the regions.

For a tropospheric release of radionuclides there is very little transfer of material to the opposite hemisphere. Therefore the radioactive release from the Chernobyl accident was largely confined to the northern hemisphere. From the estimated ^{137}Cs deposition densities of regions throughout the hemisphere, including the oceans, and the areas of these regions, an estimate was made of the total amount of ^{137}Cs released in the accident. This estimate was 70 PBq, corresponding to 25% of the ^{137}Cs calculated to have been in the reactor core. This result was nearly a factor of 2 greater than the estimate of the release made at the time of the accident, based on measurements at the release site. Revised estimates of the fractional release of ^{137}Cs from the damaged reactor are now placed at 33% of the core inventory, equivalent to a release of 85 PBq. This is in closer agreement to the UNSCEAR result derived from analysis of the widespread ^{137}Cs deposition. The amount of ^{131}I released was initially decay-corrected to 6 May, the end of the active release period. UNSCEAR also made reference to this value. Correction to

26 April, the initiation of the releases, gives an estimate of ^{131}I release of 53% of the core inventory.

6. COLLECTIVE DOSE COMMITMENT

Based on ^{137}Cs deposition estimates in all regions of the northern hemisphere, derived from the deposition–distance relationship, and the transfer factors relevant for the latitudinal area, the effective dose commitments for all regions have been evaluated. These doses times the populations of the regions give the collective effective dose commitments. The total collective dose committed by the Chernobyl accident is estimated to be 600 000 man·Sv. This is distributed 53% to European countries, 36% to the former USSR, and the remaining 11% to other regions of the northern hemisphere.

The calculation indicated that 70% of the collective dose is due to ^{137}Cs, 20% to ^{134}Cs, 6% to ^{131}I and the remaining 4% to short-lived radionuclides deposited immediately after the accident. The lifetime dose was approximately 60% from external irradiation and 40% from ingestion, on average. These proportions shift towards more external irradiation at more northerly latitude and towards greater relative proportions of internal exposure at more southerly latitudes.

7. CONCLUSIONS

The assessment by UNSCEAR of the worldwide exposures resulting from the Chernobyl accident documents in some detail this radiation experience and provides a basic methodology for dose evaluation from a large-scale accidental release of radioactive materials. The details from measurements made following the accident have allowed refinements to be made in the environmental models. In particular, seasonal features of depositions can now be taken into account and, presumably, estimated transfers of radionuclides to the body will be in better agreement with whole-body measurements than was previously the case.

Of the 600 000 man·Sv total effective dose committed by the accident, approximately one third was received during the first year following the accident. The remainder will be delivered over some tens of years, mainly according to the radioactive half-life of ^{137}Cs (30 years). During this period natural background radiation will have contributed significantly greater doses to the world's population. The collective dose from fallout radiation and the natural background collective dose in just one year far exceed the collective dose from the Chernobyl accident. Thus, from this perspective, the collective dose from the accident was not of great magnitude. Still, there was widespread contamination that caused alarming short-term increases in the background exposure levels of populations in many countries.

Having completed the evaluation of the worldwide exposures from the accident, the next step will be to look more closely at the local doses and effects. The doses were higher to populations living in the affected regions of Ukraine, Belarus and the Russian Federation, and the increased incidence of thyroid cancer in children in these areas is now recognized. It will take some time to complete the dose reconstruction for these persons and to evaluate the health effects that occur, but the results from the epidemiological studies would seem to be valuable. UNSCEAR will include available results in its next published report, to be published probably in 1998. Much will be learned from the long-term study of the effects of this unfortunate radiation experience and the differences caused by the particular conditions that prevailed in this circumstance. It is to be hoped that an atmosphere of misinformation can be avoided, which through undue stress and anxiety probably detracts the most from good health in this population. UNSCEAR looks forward to the scientific dialogue that will continue. I hope that the forthcoming assessment by UNSCEAR will be a contribution to further scientific understanding of the sources and effects of radiation and to an accurate appreciation of the risks that entail from this unique physical entity — ionizing radiation.

ONE DECADE AFTER CHERNOBYL: THE FAO RESPONSE*

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1. INTRODUCTION

The accident at Chernobyl resulted in contamination of agricultural land, not only in the vicinity of the reactor but also hundreds and even thousands of kilometres from the accident site; even today, 10 years after the accident, movement restrictions are still in place for livestock and game animals as far away as the United Kingdom and Norway. Therefore, one of the lessons to be learned from this accident is that contingency plans are needed to ensure that a range of appropriate countermeasures are available for prompt use to reduce contamination of agricultural produce, not only in the vicinity of the accident but in all countries, even in those with no nuclear facilities or programmes of their own.

The main aims in developing an agricultural countermeasures strategy are:

— To protect human health by reducing radioactive contamination of food and agricultural products;
— To return the land to productive use as far as, and as soon as, possible;
— To ensure that the countermeasures applied take account of costs to government, benefits to human health, disruption of daily life, and the social, cultural and economic well-being of communities;

* The Food and Agriculture Organization of the United Nations, primarily its Food and Nutrition Division in Rome, and the Vienna based Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, and the associated FAO/IAEA Agriculture and Biotechnology Laboratory, Agency's Laboratories, Seibersdorf.

— To assure a population, potentially exposed to radiation, that the authorities have a countermeasure strategy which is well planned, quickly implementable and compatible with that of neighbouring countries.

To achieve these aims, consideration must be given to defining radiation levels for foods and feedstuffs at which action is necessary and to establishing a range of countermeasures for important agricultural systems under likely post-accident scenarios.

2. INTERVENTION CRITERIA AND LEVELS

2.1. Development

The Chernobyl accident drew attention to discrepancies in the application of both the principles and guidance for intervention. As a result, some of the more extreme actions taken could have been avoided if more uniform standards of action had been available. Furthermore, the accident caused contamination across national boundaries and there were many instances of contradictory national responses.

A problem which the Chernobyl accident brought to the fore was the conflict between basic legislation, prohibiting shipping or sale of food contaminated with deleterious substances, and the underlying philosophy used in the area of radiation protection. This philosophy takes into account that there is a certain level of 'background radiation' due to naturally occurring radiation from the earth and from outer space, as well as man-made sources such as fall-out or contamination from nuclear weapons testing, nuclear power generation, nuclear accidents and industrial and medical uses. Preventing *all* exposure of man and animal/plant life from this radiation is not possible. Therefore, basic intervention measures are designed to reduce total exposure to radiation *in excess of* background levels to as low as reasonably achievable. While such measures have been generally accepted with regard to radiation exposure in man, they are not easily applicable to goods in commerce such as food or other agricultural products.

In the area of food legislation there are general prohibitions against unsafe levels of contamination in foods and there is no particular differentiation between different contaminants. Pesticide residues, heavy metals, mycotoxins, pathogenic micro-organisms or radionuclides are all contaminants which must be controlled by food legislation and its application. If a food contaminant is shown to present some risk to human health, food legislation requires its strict control. *If at low levels of contamination the risk to health is low, negligible or difficult to eliminate altogether, food legislation allows for the setting of contaminant or residue levels.* It also allows for the orderly trade in foods when contamination does not exceed these set limits.

The limits must be fixed so that they can be easily understood and applied by food law enforcement officers including customs officials or others controlling various aspects of domestic or international trade in foods.

Just prior to the Chernobyl accident, the international community had developed guidelines to assist competent national authorities apply established basic principles for intervention [1]. Then, in 1986, the Commission of the European Communities (CEC) published a report on Derived Emergency Reference Levels in Widely Distributed Foodstuffs [2]; these limits were identical with those established by the US Food and Drug Administration after the Chernobyl accident to control the level of radionuclide contamination in foods imported into the United States of America from areas affected by the accident fallout. The IAEA in turn published Safety Series No. 81, which addressed the principles, procedures and data needed to establish levels of dose at which relevant protective measures should be introduced — so-called derived intervention levels (DILs) [3]. Also in 1986, the Food and Agriculture Organization of the United Nations (FAO) formed an expert group to recommend limits for radionuclide contamination in food [4]. In 1988, the IAEA published its Revised Guidance on the Principles for Establishing Intervention Levels for the Protection of the Public in the Event of a Nuclear Accident or Radiological Emergency [5], the World Health Organization (WHO) published its Derived Intervention Levels for Radionuclides in Food [6], and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) published a report on Sources, Effects and Risks of Ionizing Radiation [7]. In 1990, the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD) produced its 'intervention levels for protection of the public' [8].

Many of the foregoing publications considered overall approaches to the protection of the public and the environment from exposure to radiation from all sources, except radiation from medical applications. However, it became clear from the experience of the Chernobyl accident that there was still a need to develop a set of simple generic intervention levels that could be applied internationally for most circumstances, with shipments of foods and other agricultural products as an exception. There are a number of advantages in using internationally recognized intervention levels: (1) maintaining credibility, confidence and trust in national authorities; (2) preventing anomalies that might otherwise exist along borders of neighbouring countries; (3) strong arguments can be made to adopt international values as national intervention levels for control of food. Further, as many countries have no nuclear facilities and hence no detailed emergency plan themselves, an internationally agreed set would assist them in the event of transboundary releases. In the case of foods, there is a need for clear and easily applied *finite limits for radionuclide contamination in specific food products* (see Section 2.2), although such limits can also be incorporated into more general radiation protection texts.

2.2. Generic intervention levels for foods

The FAO (1987) and WHO (1988) individually addressed various aspects of contamination of foods with radionuclides. Subsequently, the FAO/WHO Codex Alimentarius Commission [12] developed Codex international standards for radionuclide contamination to be applied to food moving in international trade.

2.3. Overall intervention guidance

In April 1993, an IAEA Advisory Group developed proposals that were published in a Technical Document (IAEA-TECDOC-698) entitled Generic Intervention Levels for Protecting the Public in the Event of a Nuclear Accident or Radiological Emergency [9]. This interim report was circulated for comment to all 124 Member States of the IAEA and to relevant international organizations. Taking account of the many comments received, an IAEA Technical Committee Meeting on Intervention after Accidents modified the text and values proposed in IAEA-TECDOC-698. Safety Series No. 109 [10] is the result of that process and represents an international understanding of the principles for intervention and numerical values for generic intervention levels.

The recommendations of this Safety Guide are the basis for the standards and numerical guidance related to intervention contained in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [11] of the FAO, the IAEA, the International Labour Organisation (ILO), the NEA/OECD, the Pan American Health Organization (PAHO) and the WHO. They take into account the FAO/WHO Codex Alimentarius guidelines on Levels of Radionuclides in Food Following Accidental Nuclear Contamination (1989) [12] (see Table I) and the new recommendations of the International Commission on Radiological Protection (1991) [13], and the conclusions and recommendations of the International Chernobyl Project on the Assessment of Radiological Consequences and Evaluation of Protective Measures (1991) [14]. It is noteworthy that the World Trade Organization, under the Uruguay Agreement on the Application of Sanitary and Phytosanitary Measures, will consider the FAO/WHO Codex Alimentarius levels for all contaminants, including radionuclides, as the benchmark standards for foods moving in international trade.

The levels given in Table I are designed to be applied only to radionuclides contaminating food moving in international trade following an accident and not to naturally occurring radionuclides which have always been present in the diet. The Codex Alimentarius guideline levels remain applicable for one year following a nuclear accident, i.e. a situation where the uncontrolled release of radionuclides to the environment results in the contamination of food offered in international trade.

TABLE I. GUIDELINE LEVELS FOR RADIONUCLIDES IN FOODS FOLLOWING ACCIDENTAL NUCLEAR CONTAMINATION FOR USE IN INTERNATIONAL TRADE[a]

Dose per unit intake factor (Sv/Bq)	Representative radionuclides	Level (Bq/kg)
Foods detined for general consumption		
10^{-6}	^{241}Am, ^{239}Pu	10
10^{-7}	^{90}Sr	100
10^{-8}	^{131}I, ^{134}Cs, ^{137}Cs	1000
Milk and infant foods		
10^{-5}	^{241}Am, ^{239}Pu	1
10^{-7}	^{131}I, ^{90}Sr	100
10^{-8}	^{134}Cs, ^{137}Cs	1000

[a] FAO/WHO, Codex Alimentarius, Vol. 1A, CAC/6L 5 [12].

Following existing risk assessment procedures for contaminants in foods, the proposed levels were derived using conservative assumptions based on the no-effect or minimal level. Using the Codex guidelines, the activity of the accidentally contaminating radionuclides within a dose per unit intake group should be added together if more than one radionuclide is present. Thus the 1000 Bq/kg level for the 10^{-8} Sv/Bq dose per unit intake group is the total of all contaminants assigned to that group. For example, following a power reactor accident, ^{134}Cs and ^{137}Cs could be contaminants of food, and the 1000 Bq/kg refers to the summed activity of both these radionuclides. These levels are intended to be applied to food prepared for consumption. They would be unnecessarily restrictive if applied to dried or concentrated food prior to dilution or reconstitution. The levels apply to situations where alternative food supplies are readily available. Where food supplies are scarce, higher levels can apply.

Both the FAO and WHO have called attention in the expert meeting reports to special consideration that might apply to certain classes of food which are consumed in small quantities, such as spices. Some of the foods grown in the areas affected by the Chernobyl accident fallout contained very high levels of radionuclides following the accident. Because they represent a very small percentage of total diets and hence would be very small additions to the total dose, application of the guideline levels to products of this type may be unnecessarily restrictive. The FAO and WHO are aware that policies vary at present in different countries regarding such classes of food.

TABLE II. SPECIFIC INTERVENTION LEVELS (OR TEMPORARY PERMISSIBLE LEVELS) CURRENTLY EMPLOYED IN CONTAMINATED AREAS[a] OF CIS COUNTRIES (1995) FOR WITHHOLDING FOODS FROM HUMAN CONSUMPTION

	^{137}Cs in milk (Bq/L)	^{137}Cs in meat (Bq/kg)
Belarus	111[b]	600
Ukraine	370	740
Russian Federation	370	740

[a] Defined as areas where depositions of ^{137}Cs, ^{90}Sr and ^{239}Pu fallout still exceed 1, 0.15 and 0.01 Ci/km^2 (37, 5, 0.4 kBq/m^2) respectively.

[b] Some contaminated districts use even lower levels (e.g. the Gomel region uses 37 Bq/L milk and 370 Bq/kg meat).

The Codex Alimentarius general intervention levels apply to foods in international trade. They do not necessarily apply to national control measures if alternative food is not available, in which case higher values may need to be utilized because of food availability and other accident and site specific conditions. For example, the cost of resources and societal disruption may be insupportable with the available national resources, and relaxation of the intervention levels may be necessary. On the other hand, when the numbers of people and the area of land potentially affected are very small, relatively high costs may be justified in order to achieve intervention levels and thereby gain public confidence.

In practice, the specific intervention levels used in CIS countries differ from the guideline levels (see Table II). Thus, there can be circumstances where national and local authorities believe there is good reason for requiring food on the market to have lower levels of radionuclides than those proposed in generic guidelines. Such decisions may be based, for example, on the additional contribution of external exposure to the total dose in certain localities.

3. AGRICULTURAL COUNTERMEASURES

3.1. Range of activities

The FAO and its IAEA collaborators have been involved in a number of activities related to agricultural countermeasures. The first involved the collation of the information and experience acquired after the Chernobyl accident in order to prepare guidelines for agricultural countermeasures; these published guidelines include technical matters and address related administrative issues. Ongoing activities include the provision of assistance to affected Member States to develop and implement particular countermeasures, and support work to generate data that can be used to refine existing countermeasures or develop new ones.

3.2. Guidelines for agricultural countermeasures following an accidental release of radionuclides [15][2]

The Chernobyl accident, directly or indirectly, stimulated considerable scientific research and much practical experience was obtained by those dealing with its consequences.

The information generated is summarized here. Work began in 1990 with a co-ordinated research programme of the IAEA and the CEC on the Validation of Models for the Transfer of Radionuclides in Terrestrial, Urban and Aquatic Environments (VAMP), and continued with a joint programme of the IAEA Division of Nuclear Safety and the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture entitled Alleviating the Adverse Effects of Excessive Radionuclide Contamination of the Agricultural Environment. The final document was prepared with the help of nearly 40 scientists from 19 countries and aims to give general advice on the development of emergency response plans. It has three objectives:

- To establish a general strategy for the introduction of agricultural countermeasures following an accidental release;
- To compile and collate data on available countermeasures for use in decision making;
- To assist Member States in the preparation of their detailed guidelines specific to their circumstances.

In the event of a nuclear accident, the effectiveness of measures taken to protect the agricultural sector (people, land, crops and livestock) will depend upon the adequacy of emergency plans prepared in advance. The Guidelines outline a strategy for the development of such emergency plans which should specify criteria for taking particular prompt action. After the immediate emergency, predefined criteria for longer term action will do much to sustain public confidence in the competence and integrity of the authorities. Such criteria for intervention are based on minimizing the radiological dose. However, ecological, economic and social factors must also be considered, as any measures taken should clearly do more good than harm to the communities involved.

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[2] A Russian translation is available as IAEA-TECDOC-745.

The Guidelines recognize two distinct phases in which to consider countermeasures. In the phase of planning and preparation, prior to accidents, a *generic* assessment of protective actions should be established, based on a *generic* accident scenario calculation. This would result, for each protective measure and each selected scenario, in an optimized *generic* intervention level, which is meant to be the first criterion for action to be used immediately and for a short time after the occurrence of an accident. These plans require a database which includes locally determined transfer factors for the radioisotopes Cs and Sr, information on soils, weather patterns, local dietary preferences and some feasible countermeasures with estimates of their costs. A network of laboratories for radionuclide analysis must also be identified.

Some time after the beginning of an accident, specific information on its nature, its likely consequences and its evolution would be expected to be available. In the event, a more precise and *specific* optimization analysis should be carried out on the basis of actual data and the actual efficiency of protective measures. This should result in a *specific* intervention level for each protective measure, to be used as criteria in the medium and long term. However, in many cases the choice of countermeasures will be constrained by sociopolitical and economic factors, so it is important that the database for decision making includes information about social factors and infrastructure of the region.

The Guidelines then go on to consider particular agricultural countermeasures with some assessment of their efficacy. Such countermeasures address stochastic health effects in the human population; the more immediate impact of radiation exposure on plant and animal life is not directly considered.

Although a large number of radionuclides can be released in a nuclear accident, those of agricultural importance meet one or more of the following criteria:

— they have a comparatively long half-life,
— they have high radiological toxicity,
— they are potentially highly mobile in the environment,
— they are biologically essential or are closely related to such an element.

In practice, the nuclides considered to be of most importance are ^{131}I, ^{134}Cs, ^{137}Cs and ^{90}Sr.

Some measures can be taken before and during deposition of radioactive fallout. Thus, direct contamination can be prevented by housing animals or covering feed/food stores. Given adequate warning, it may be possible to harvest a crop (grass, grain, cash crop) before deposition of fallout.

The next group of countermeasures are those to be applied in the first few weeks after deposition, particularly to reduce exposure from short-lived radionuclides such as ^{131}I. Thus, crops may be harvested and stored, or harvesting may be delayed, to allow for radioactive decay before consumption. Similarly, milk contaminated with ^{131}I can be converted to storable products (e.g. milk powder, cheese).

Once radioactive contamination is distributed through the biosphere, a wider range of countermeasures can come into play. The most effective countermeasures take into consideration the transfer factors of the relevant radionuclides through local soils. For example, since ion uptake by plants is related to the quantities available and the relative abundance of different ions, the application of high levels of potassium fertilizer can reduce Cs uptake; and liming, by increasing calcium levels, can reduce ^{90}Sr uptake. Liming also raises the soil pH and hence its cation exchange capacity, so reducing the availability of radionuclide cations. In some situations it is possible to use alternative varieties or crops that accumulate lower levels of radionuclides than the varieties or crops normally grown in a region, e.g. cereals in place of leafy vegetables and pasture. Another possibility is to grow crops such as sugar-beet or rape-seed where the edible product is processed and contamination reduced. Deep ploughing to dilute soil contamination can be useful or the surface soil may even be removed. It is important to maintain some form of agricultural production wherever possible, so in some circumstances growing crops, such as flax, cotton, rape-seed for biofuel, or ornamental plants where the product is not consumed, must be considered.

Contamination of animal products can be reduced most effectively by limiting the intake of radionuclides or reducing their absorption. Feeding uncontaminated stored feedstuffs is an example of the first category, while the use of Prussian Blue (discussed in more detail in Section 3.3) is an example of the latter. In the case of meat producing animals, feeding uncontaminated feed may only be necessary close to the time of slaughter, since the biological half-life of radiocaesium, for example, is of the order of 2–4 weeks, depending on the species. This strategy can be supplemented by monitoring the animals in the slaughterhouse or at the farm to identify those that require a further period of feeding with uncontaminated material. With game animals, changing the hunting season may be effective where the animals have seasonal feeding habits. For example, mushrooms and lichens, which can be highly contaminated, are frequently most abundant in autumn, so animals should not be hunted in this period.

There are a number of other more or less specific countermeasures reviewed in the Guidelines; those mentioned above are merely examples. However, decisions on whether to apply countermeasures and which ones are appropriate depend on the availability of adequate information about both the nature and extent of radioactive contamination. Since a considerable infrastructure is necessary to produce an effective response, a substantial section of the Guidelines is concerned with guidance on the organizational structures required. Finally, a brief review of the responses of selected countries to the Chernobyl accident is given.

3.3. **Assistance with particular countermeasures** (see Table III)

3.3.1. After the Chernobyl accident, many different countermeasures were employed in affected countries to ensure that foodstuffs produced for general

TABLE III. ONGOING FAO/IAEA ACTIVITIES

Type of activity	Country	Project title	Duration	Budget (1000 US $)
IAEA Technical co-operation projects	Belarus	Rapeseed Cultivation on Soils Contaminated by Radionuclides	4 years	1000 for equipment, expert services and training
	Belarus	Migration of Radionuclides in Contaminated Soils	2 years	
	Belarus	Establishing Regulatory Procedures and Standards Laboratory	2 years	
	Ukraine	Reduction of Radionuclides in Milk by Magnetic Separation	4 years	
FAO/IAEA co-ordinated research programmes	Tropical and sub-tropical countries	Transfer of Radionuclides from Air, Soil and Freshwater to the Food Chain of Man in Tropical and Sub-tropical Environments	1993–1997	150
	South-east Asia	Efficacy in Tropical Crops of Countermeasures to Reduce the Uptake of Radionuclides	1996–1999	150
	Europe and CIS	Methods to Reduce the Uptake of ^{90}Sr by Animals Consuming Contaminated Fodder	1996–1999	150
Publications	CIS	A United Nations Document on the Use of Caesium Binders to Reduce Radiocaesium Contamination of Farm Products from the Territories of Ukraine, Belarus and the Russian Federation	1996	150

consumption had radiocaesium (and radiostrontium) levels below each State's acceptable levels. For instance, in Belarus, Ukraine and western Russia, contaminated pasture land on State and collective farms was deep ploughed and re-seeded, lime and potassium fertilizers were applied to reduce radiocaesium uptake by plants, and 'clean' foodstuffs were brought in for livestock. These and other countermeasures led to a significant reduction in radiocaesium contamination of milk and meat produced at the State level. However, on farm land owned by the small farmer communities, the application of such countermeasures was not possible, largely for economic reasons. Despite this, it was estimated in 1992 that up to 50 000 dairy cows kept by small farmers were still producing milk that exceeded the permissible levels (111 Bq/L in Belarus; 370 Bq/L in Ukraine and Russia). Therefore, an alternative approach was required which was simple, effective and cheap.

Through a project sponsored by the Norwegian Government, a countermeasure was developed to lower the levels of radiocaesium in both domesticated and game ruminants, based on the use of a mixture of compounds known as Prussian Blue (PB). Executed through the United Nations, the project involved the Norwegian Agricultural University and Radiation Hygiene Institute, the Ukrainian Research Institute of Agricultural Radiology in Kiev, the Byelorussian Branch of the All-Union Institute of Agricultural Radiology in Obninsk and The Queen's University in Belfast. The project was implemented by the Food and Agriculture Organization of the United Nations, with the IAEA providing technical leadership. The Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, the IAEA's Division of Nuclear Safety and the Agency's Laboratories in Seibersdorf provided co-ordination, expert services, equipment and materials to the major counterpart institutes in the CIS for conducting trials in the worst affected villages.

Following successful trials in 1990–1992 involving over 3000 cows in 21 settlements in Belarus, 10 000 cows in 54 settlements in Ukraine and an unspecified number of cattle in villages in Russia, each State's Minister of Agriculture authorized the widespread use of PB in livestock for reducing the content of ^{137}Cs in milk and meat.

The term Prussian Blue refers to a number of ferric hexacyano ferrates; ammonium ferric cyanoferrate (or AFCF) is perhaps the most commonly used caesium binding compound. Given as a bolus into the rumen or else as a compounded concentrate additive or a salt lick, or simply sprinkled on the diet, AFCF assumes a colloidal nature in the intestine of cattle and sheep where it reacts with consumed radiocaesium to form a complex that does not penetrate biological membranes. Dietary supplementation with PB compounds thus has the same effect as feeding clean feed; excreted in the dung, the PB-bound radiocaesium is taken up at a reduced rate by plants, so providing an additional benefit. Depending on the dose and type of PB compound given, twofold to eightfold radiocaesium reductions are observed in milk (Fig. 1) and meat from cattle grazing contaminated fodder (more details on this are given in Poster 423, presented at the conference). This results in a significant reduction

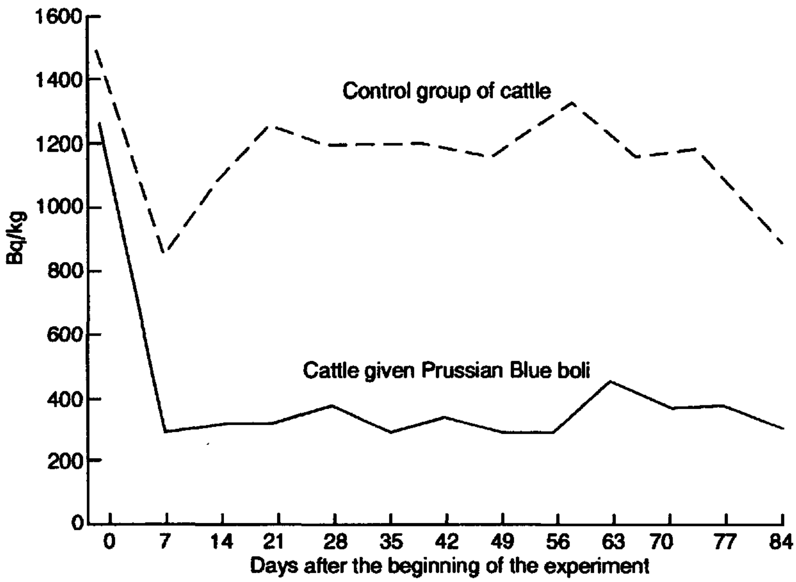

FIG. 1. Levels of ^{137}Cs in cows' milk: Results of field trials. Experiments were conducted in the village of Velikiye Ozera. Three boli per animal were introduced at day 0 and day 52.

in internal dose and is often of sufficient magnitude to allow the village communities to remain within the contaminated areas. As a result, the traumatic experience of translocating whole communities, which was previously commonly practised, has been curtailed and the huge cost to government has been alleviated. The socio-economic benefits of employing PB compounds have therefore been enormous and greatly welcomed by farmers and government alike as it significantly reduces the likelihood, trauma and cost of translocation.

3.3.2. Whereas the application of countermeasures on State and collective farms has been generally successful, and foodstuffs (e.g. grain) are now cultivated on previously contaminated land, public acceptance of 'clean' foods coming from 'Chernobyl' areas is still a problem. The Belarusian and Ukrainian authorities are thus anxious to utilize the 'contaminated' land in an alternative way which will yield better economic return. Through its joint programme with FAO, the IAEA's Technical Co-operation Department is currently supporting a project in Belarus to investigate the potential of oil-seed crops (primarily rape-seed) as an alternative cash crop. Initial research indicates that oil produced from certain varieties of rape-seed on land with radiocaesium levels of 15–40 Ci/km^2 is devoid of the radionuclide (and ^{90}Sr); the contamination is restricted to the straw and oil-seed meal. The Belarus authorities sowed approximately 20 000 ha of contaminated land with rape-seed in 1995 and intend refining the oil into bio-lubricants — a much needed, currently imported, resource. Should the project be successful, the land area sown will be expanded two- to threefold for lubricant production.

IAEA Technical Co-operation assistance is also being given to Ukraine, to improve the skills and facilities for the measurement, control and reduction of radionuclides in foodstuffs. The initial emphasis is on dairy products, with particular reference to the Ovruch Milk Canning Integrated Works, processing up to 200–500 t of milk per day, much of it from farms within the Chernobyl contaminated zone. The US Government is currently supporting this activity with resources to explore the possibility of decontaminating incoming liquid milk from farms affected by the accident through employing a commercial magnetic separation system.

3.4. Generation of data

Additional assistance is being given to Belarus, through the IAEA Technical Co-operation programme, to improve the database on the occurrence and migration of radionuclides in soils, forests and waterbodies to allow forecasts to be made of the likelihood of success and the time required for the restoration of contaminated regions to normal economic activity.

Parameter values for the transfer of radionuclides between environmental compartments and experience of dealing with the consequences of a nuclear accident are largely confined to temperate regions, primarily in Europe [16]. However, the geographical distribution of nuclear power stations is such that it is conceivable that an accident could also affect tropical countries. Therefore, an FAO/IAEA Co-ordinated Research Programme is in progress to measure transfer factors for Cs and Sr from soil to the major tropical crops and also from water to tropical fish. These data will also be of value in establishing permissible levels of radionuclides in industrial effluents in the tropics. There are also plans to establish a further co-ordinated research programme which will examine the efficacy in tropical crops of countermeasures that have proved effective in Europe.

4. FUTURE ACTIVITIES

There is a need for authorities to develop secondary reference levels (so-called operational intervention levels) for animal feeds and pasture.

The problem of contaminated forests has received insufficient attention from the international community, although a Technical Committee has been established by the IAEA to develop a model for aiding decisions on their management and utilization.

A range of agricultural countermeasures is currently available to reduce the impact of radiocaesium contamination in the food chain. The same cannot be said for radiostrontium contamination. Considerable laboratory and field research and development are required to address this major contaminant. For example, a number of materials have been proposed for selectively absorbing/adsorbing strontium in foodstuffs, but none can yet be recommended unequivocally because data are inadequate. Alternative approaches, such as the use of filters and magnetic separators for liquid food products, are currently available commercially, although they have not been evaluated critically under the conditions prevailing in the contamined regions.

In devising and applying agricultural countermeasures, due consideration should in future be given to the management of the contaminated natural environments in general, especially forests and waterbodies surrounding agricultural land.

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KEYNOTE PRESENTATION FROM THE OECD/NEA

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Presentation by H. Métivier

The Chernobyl accident, occurring several years after the 1979 Three Mile Island (TMI) accident in the United States of America, completely changed the society's perception of nuclear risk. The TMI accident led to new research programmes on the safety of nuclear reactors. The Chernobyl accident, with its death toll and the dispersion of a large part of the reactor core material into the environment, raised a large number of 'management' problems, not only for the treatment of exposed persons but also for the necessary decisions affecting the population and for estimations of the consequences in terms of late effects.

Many improvements in radiation protection and emergency preparedness have been made possible by the experience gained from the Chernobyl accident, and it is now possible to arrive at a more accurate assessment of its impact. The fact is that knowledge of the future consequences of the accident in terms of health effects remains imprecise, for technical reasons, which lends itself to a competition between those who want to minimize the consequences and those who wish to promote a catastrophic assessment. More positive is the beginning of a new competition between those who strictly apply the precautionary principle for all situations and those who prefer to use scientific knowledge when it exists and if it can dispel doubt.

In these circumstances, having discussed in 1994 the question of the future of radiation protection, the Committee on Radiation Protection and Public Health (CRPPH) of the Nuclear Energy Agency of the OECD wished to make an honest assessment, ten years on, of the Chernobyl accident, the state of contaminated territories and the state of health of the populations, and to attempt an appreciation of the likely risks, not only for humans but also for the environment.

This report was not the first one by the OECD: one year after the accident, the CRPPH published a report on the radiological impact of the Chernobyl accident in OECD countries.

This new report is not an exhaustive one in which scientists will find the data they need for a further evaluation. These are now available in several scientific reports. I wish to cite the efforts made to date by the WHO, the European Commission, UNSCEAR and the IAEA. The OECD/NEA report is targeted at decision makers for whom an overflow of information has the same result as no information.

The CRPPH also details the lessons that have been learned by member countries and international organizations. It has also organized international emergency exercises (INEX), under the INEX Programme. INEX 1 is published; three follow-up meetings, in Sweden, France and Switzerland, were organized to analyse some critical points. We are preparing INEX 2.

This report was prepared by P. Waight as consultant, under the direction of an editorial committee. The members of this committee, which I chaired, were: H. Métivier (IPSN, France) P. Jacob (GSF, Germany), G. Souchkevitch (WHO, Geneva), H. Brunner (NAZ, Switzerland), C. Viktorsson (SKI, Sweden), B. Bennett (UNSCEAR, Vienna), R. Hance (FAO/IAEA, Vienna), S. Kumazawa (JAERI, Japan), N. Kusumi (IRE, Japan), A. Bouville (NCI, USA), J. Sinnaeve (EC, Brussels); O. Ilari and E. Lazo (OECD/NEA, Paris).

Before I give the floor to P. Waight, on behalf of OECD/NEA/CRPPH and myself, I wish to thank again all the members of this committee, and more especially P. Waight for his competence and patience during the three meetings needed for the preparation of this report.

Presentation by P. Waight

The report on Chernobyl: Ten years on, produced by the Committee on Radiation Protection and Public Health (CRPPH) of the Nuclear Energy Agency of the OECD, is an overview of the accident for the intelligent layman with minimal specialized knowledge. It provides a consensus overview of the accident and its impact in terms that can be readily understood by decision makers, journalists and the general public. It is my job today to try and give you a flavour of some of its content. The report traces the development of the accident and describes the releases and the deposition of radionuclides, and the dose estimates that were made. The health and agricultural impacts are discussed, as are the potential residual risks, and the report ends with a summary of the lessons learned. I think that it provides a balanced view for persons who are not too familiar with some aspects of the accident, whether they are specialists in one particular aspect or whether they are interested laypersons.

I cannot possibly provide you with a comprehensive summary, so it would seem reasonable to choose one aspect to discuss. The fact that such items as the thyroid effects and the sarcophagus are the subjects of detailed discussion at this conference precludes them from this general presentation, so I have chosen to review some of the lessons that it is felt have been learned.

The initial lesson is that although the Chernobyl accident revealed many deficiencies in emergency plans, it should not be elevated to the status of a reference accident, since the next major accident will assuredly be different. It is essential not to fall into the trap, previously attributed, probably apocryphally, to the military, of planning for the next war on the basis of the previous one. It is clear that this accident exposed deficiencies in many areas, but it should not become the sole basis for planning for future severe accidents.

Many lessons were learned, but they were not all applicable to the same extent in every country. Depending on the particular circumstancs of a country, emphasis was placed on different aspects. Thus, countries with their own nuclear power programmes, or a neighbouring country with power reactors, drew heavily on this experience to remedy deficiencies in their planned management of a severe accident. Countries with no power reactors either on their own territory or on adjoining territory concentrated on food control and information exchange as their main priorities. In spite of this selective approach by individual countries, certain generic lessons with wide application were drawn.

Most national authorities were taken by surprise at the magnitude and extent of the accident. Such a severe accident had not been considered likely enough to figure in the plans of most countries with nuclear power programmes, and no one had foreseen the need to plan for the transboundary consequences that resulted. The effect was that national authorities often reacted precipitously in response to social, economic or political pressures, rather than in accordance with radiation protection principles.

The accident also revealed other deficiencies in the existing plans to deal with a major accident. Much confusion existed in many countries as to where the responsibility for particular actions lay. Responsibilities within government departments were unclear and jurisdictions often overlapped, leading to hasty, ad hoc and wrong decisions. Decisions on the introduction of countermeasures were again made on a case by case basis in the course of the accident, wasting time and resources, so that optimal implementation might well have been missed. It was clear that *all plans needed to be well rehearsed and in place to minimize the need for time consuming ad hoc decisions; that all plans needed to clearly demarcate responsibilities and jurisdictions; and that the levels at which countermeasures should be introduced should be agreed in advance. In fact, perhaps the golden rule is to decide everything in advance that can possibly be decided, allowing time to manage the evolution of the accident.*

It is not enough to have detailed emergency plans; a permanent infrastructure to implement these plans must be created and maintained. This infrastructure will ensure continuous revision of the accident management plans as developments in concepts and technology occur. It will also ensure that exercises are regularly held to test the efficiency of the plans and the feasibility of any changes.

It is only too easy, especially in these times of financial constraints, for national authorities to be led into thinking that this infrastructure is an unnecessary luxury and that it should be curtailed. While it is obvious that some countries have a greater need of and can afford a very sophisticated system, it would be extremely short-sighted to dismantle an existing infrastructure purely for cost savings.

Some components of the permanent infrastructure are worthy of special mention. *Communication* is an essential area which can have far-reaching effects on the efficient management of an accident. Internal communication must be established between the functional units dealing with the accident, and information must be effectively channelled to the people on a continuing basis to keep them informed. An international communication channel is required also to keep neighbouring and even distant countries informed of the evolution of the accident. *Intervention teams* for specialized tasks such as fire-fighting and decontamination need to be specially trained in advance so that they are available at the time of the accident. *Monitoring* is an essential function, which requires not only a permanent *network* to make accurate environmental measurements but also *mobile teams* to make field measurements and collect samples. The capability of taking *aerial* samples to track a plume may be essential in some types of accident. A large amount of data will be collected and produced, so that uniformity of collection, handling and presentation will only be possible through *centralized computer data management.*

There were *international implications* of the Chernobyl accident. The trans-boundary aspects of the contamination meant that no single country could plan for such a severe accident, and that international co-operation and communication were required in the management of the accident. Actions needed to be harmonized in order to avoid apparent conflict between measures adopted by different countries, and agreement needed to be reached on the type of co-operation between States that was required. This has been achieved in a number of ways.

A major accomplishment of the international community was the ratification of *Conventions* on early notification and assistance in the event of a radiological accident, which were achieved within the framework of the IAEA and the EC. Many of you were involved in these discussions and know how difficult it was on occasion to reach consensus. I can recall the difficulty that was experienced in reaching agreement on the *WHO/FAO Codex Alimentarius* levels for contamination in food-stuffs moving in international trade, where some countries with no nuclear power programmes of their own considered that they should not accept any radioactive contamination at all in their imported food. Many of these agreements were reached not only at the instigation of the international organizations but also as a result of their persistence.

Other international organizations such as the ICRP were heavily involved in reaching a clear and harmonized philosophy for accident management. Because ICRP Publication No. 40 met with such varied interpretation at the time of the accident, the ICRP attempted with Publication No. 63 to provide unequivocal advice for the protection of the public in a radiological emergency, on the basis of the Recommendations in ICRP Publication No. 60.

One of NEA's many activities associated with the Chernobyl accident was the development of international emergency exercises within its INEX Programme. For example, INEX 1 was a learning experience for all the participants and highlighted, among other things, the need to actively incorporate a channel of communication with the media to ensure that the public is continuously and accurately informed.

I would like now to highlight some of the more specific *scientific* and *technical lessons* learned. Naturally, I cannot mention them all, but I will try to emphasize some of the more obvious ones.

Prior to the accident it had been felt that the environmental flora and fauna were relatively resistant to the effects of radiation, but there was little evidence upon which to base this surmise. However, the accident tended to confirm this belief, as a cumulative dose of less than about 5 Gy has no major effect even on the most sensitive flora. Pine trees in the 'red forest' close to the site were found to have received doses of up to 100 Gy, resulting in the death of these trees. However, this was a relatively small area, and other investigations after the accident confirmed that no major ecological damage had occurred.

The accident had serious implications for all types of *modelling*. Plant foliar and root uptake is being extensively studied and transfer coefficients at all steps in the pathway to man have been refined, leading to more complex but realistic models for human exposure. It was found that previous models had tended to overpredict the dose to humans by a factor commonly of two to three, but possibly by a factor of up to ten.

Meteorological models have also been refined in order to better define the relationship between deposition and precipitation, as well as the influence of the topography of the terrain on deposition. The importance of synoptic weather patterns in predicting the geographical distribution of deposition has been recognized. The influence of the physico-chemical composition of the radioactive gases, aerosols and particulates on their atmospheric transport has led to refinement of the transport models.

The accident also stimulated research in the field of *nuclear safety* which was not just confined to improving the operating safety of the RBMK reactor but also embraced all aspects of safety in the operation of many reactor types. For example, this accident led to a re-examination and modification of the reactor shutdown procedure at the pressurized heavy water reactor at Pickering in Ontario, Canada.

Significant lessons were learned for the *treatment of overexposed persons*. Prior to the accident, it had been assumed that *bone marrow transplantation* would play a significant role in the treatment of the more highly exposed patients; however, it was found to be less effective than expected. It had also been assumed that haemorrhage, due to the reduced clotting ability following a reduction in platelet count, would be a significant clinical finding that would require treatment. However, even when the platelet count fell below 1000 per microlitre, bleeding was not a prominent feature. The importance of symptomatic treatment and prophylactic measures such as the administration of antibiotic, anti-fungal and anti-viral agents, air sterilization and barrier nursing was demonstrated.

This short review of one chapter in the OECD/NEA report has been an attempt to present the thrust of the report, which is intended to provide an overall scientific consensus view of the more important aspects of the accident in terms that it is hoped people will be able to understand.

GERMAN MEASUREMENTS OF THE POPULATION DOSE AROUND CHERNOBYL

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1. INTRODUCTION

The reports on the consequences of the reactor accident at Chernobyl on 26 April 1986 have been extremely contradictory. In the post-Soviet republics affected by the accident there was a general lack of reliable information concerning the levels of radioactive contamination of the environment and of foodstuffs. Where data were given, they were insufficiently supported and explained.

Not least, these circumstances led to considerable disquiet and concern amongst the public, even at a great distance from the site of the accident. In order to assist in informing those affected and above all to determine their actual radiation exposure, the Federal Republic of Germany performed a measuring campaign in the three post-Soviet republics between Moscow and Kiev in the years 1991–1993. For this purpose, the Federal Ministry of the Environment made available funds of about DM 12 million.

Starting in 1991, a total of 22 vehicles with 27 measuring assemblies and more than 150 staff, recruited on a voluntary basis from various institutions in the Federal Republic of Germany, were engaged in the first measuring campaign, lasting from mid-May to early October 1991 [1]. In the following two years the programme was slightly reduced.

Great store was set by the comprehensive information of the population. In addition to general information through the media, two leaflets were distributed to all visitors to explain the radiological situation. Each person undergoing measurements or bringing food samples received a form giving the results and a short explanation in Russian. This was favourably accepted by the public.

2. ENVIRONMENTAL MEASUREMENTS

In each settlement the measuring programme began by determining the area dose rate and the soil contamination. Subsequently, basic foodstuffs, such as water, milk, meat, potatoes, bread and cereals, were examined by gamma spectrometry as an aid to interpreting the whole-body measurements. All foodstuff supplied by the public was measured. Each participant was given the contamination result for his food sample and a brief explanation in Russian on a specially designed form.

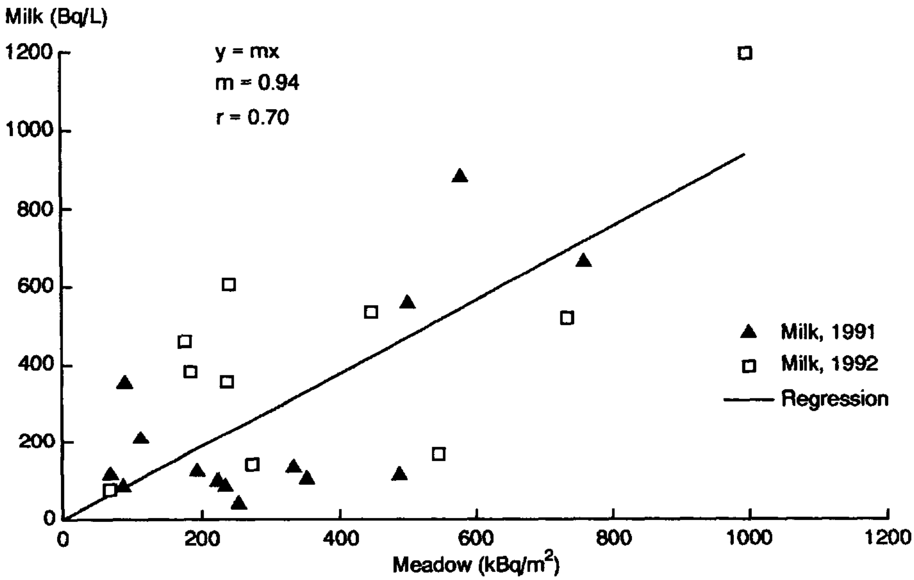

FIG. 1. Relation between caesium contamination in milk and soil contamination on meadows in 1991 and 1992.

A total of more than 4000 food measurements, more than 500 soil examinations and more than 1000 area dose rate determinations were carried out.

The strong relation between the caesium ground contamination and the area dose rate is confirmed by our measurements. The gradient of the correlation line for undisturbed ground (pastures) corresponds to a dose rate/ground contamination relationship of about 1.1 μSv/h for 1000 kB/m^2 of Cs contamination on soil. For arable land (fields) it is 0.5 μSv/h.

In 1991 the average milk concentration east of Novosybkov in the Klincy district was about 130 Bq/kg, on the basis of 227 milk samples from private farms. But maximum values were still high — the highest value was 3700 Bq/kg. In this district, the official limit of 370 Bq/kg was exceeded for 25% of all results.

A correlation was found between the milk concentration and soil contamination of pastures. The milk concentration in relation to the contamination of pastures for the years 1991 and 1992 is given in Fig. 1. The correlation is weak but evident. In 1993 the correlation could not be confirmed.

3. INCORPORATION MEASUREMENTS

Three semi-trailers with 4 measuring assemblies each and up to 4 box-type delivery vans with 2 measuring assemblies each were employed for the whole body measurements. This permitted flexible operation. The delivery vans enabled measurements to be carried out at small settlements and the semi-trailers were parked in towns or large villages where they remained stationary for a few weeks, thus permitting a high throughput.

It was to be expected that the detectable radionuclide incorporation of the population would only consist of the gamma emitters ^{137}Cs and ^{134}Cs. Even in 1990, other international projects, especially the IAEA project, could only find these radionuclides in human bodies. On the basis of the environmental and food measurements, a significant contamination of the population with ^{90}Sr and ^{239}Pu was finally ruled out.

Therefore, an important criterion for selecting the measuring systems was a sufficient detection sensitivity for the isotopes ^{137}Cs and ^{134}Cs in a short measuring time appropriate for the measuring task. It should be possible to detect a Cs activity of 1 kBq in the human body within a measuring time of 1 minute. This requirement was fulfilled not only by spectroscopic, nuclide-revolving measuring systems but also by simpler systems with plastic scintillators. This mixed system permitted mobility and cost savings, since the instruments operating radiometrically were much lighter and considerably cheaper.

For intercalibration purposes, comparative measurements were carried out each year with a whole-body phantom made available by our Russian partners from the Scientific Research Institute for Hygiene at Sea of the Ministry of Health of the former USSR.

Measurements were carried out in more than 240 settlements in the ten regions of Bryansk, Kaluga, Orel and Tula in Russia; Gomel, Mogilev and Brest in Belarus; and Kiev, Shitomir and Rovno in Ukraine.

All measured data were evaluated according to three categories. The breakdown of these categories can be seen from Table I. A differentiation was made between adults and children. The limits for children were selected in such a way that for 5- to 12-year-olds the respective dose corresponds to the limits for adults. For babies a special counter was developed and put into operation in 1992. For this group the limits were reduced once more.

TABLE I. DIVISION OF THE MEASURED DATA INTO CATEGORIES

	Adults	Children
Category 1	Up to 7 kBq	Up to 4 kBq
Category 2	7 to 25 kBq	4 to 15 kBq
Category 3	More than 25 kBq	More than 15 kBq

The limit of 7 kBq actually results in an effective dose of 0.3 mSv/a and an activity of 25 kBq leads to an effective dose of 1 mSv/a. Measurement results in the first category do not give any cause for concern. Body activities within the second category are also sufficiently safe, but in this case it was recommended to limit the intake of food known to be highly contaminated (e.g. mushrooms, game). The values in the third category do not in any case exceed the permissible limits of intake according to ICRP 30. The highest measured result was 770 kBq. For continuous uptake of ^{137}Cs the annual dose limit of 50 mSv/a corresponds to a body burden of more than 1000 kBq.

A summary of all whole body counter measurements carried out by German experts from 1991 to 1993 is given in Table II. A total of 317 011 measurements were performed in the three republics Russia, Belarus and Ukraine. The total number of measurements decreased from 163 000 in 1991 to 90 000 in 1992 and 64 000 in 1993 because of continuously reduced funding and reduced interest on the part of people who in the previous year had been found to have low exposure. Nearly 90% of all results are within category 1, about 8% are in category 2 and only 2% must be assigned to category 3.

TABLE II. SUMMARY OF ALL GERMAN WHOLE BODY COUNTER MEASUREMENTS, 1991-1993

	Number	Category 1	Category 2	Category 3
1991				
Total Russia	163 033	93.7%	5.3%	1.0%
1992				
Total	90 460	90.6%	7.9%	1.5%
Russia	49 858	85.8%	11.7%	2.5%
Ukraine (Fastov)	11 373	100%	0%	0%
Belarus	29 229	95.2%	4.4%	0.4%
1993				
Total	63 518	81.0%	14.6%	4.5%
Russia	14 836	70.0%	22.9%	7.1%
Ukraine	36 126	84.5%	11.9%	3.7%
(incl.Rovno)	2 773	38.6%	34.9%	26.5%
Belarus	12 556	83.8%	12.4%	3.8%
1991-1993				
Total	317 011	90.3%	7.9%	1.8%

Some particularities can be observed for the different republics and for different years. Thus, the category 3 fraction increased over the 3 years from 1% to 1.5% and 4.5%, probably due to the reduced interest of people with low exposure in a repetition of their measurements.

The highest fraction of category 3 results was found in 1993 in the district of Rovno, where 26.5% had to be assigned to the highest category. In Rovno in the western part of Ukraine the ground contamination is not high. Thus, the high body burden in these inundated areas demonstrates the overriding importance of transfer factors.

4. MEASUREMENTS OF THE EXTERNAL DOSE

In 1992 and 1993 the measuring programme was supplemented and completed by personal dose measurements of the external dose. They were performed in collaboration with colleagues from the Novosybkov branch of the Institute for Radiation Hygiene in St. Petersburg. The personal dose was mainly measured in Russia near the western border of the Bryansk region in the districts Novosybkov, Slinka, Klimovo, Krasnaya Gora, Gordeyevka, Klincy and Starodub. In 1992 a minor part of these measurements (about 10%) was done in the Gomel region in Belarus, in the districts Narovlya, Dobrush, Chechersk and Korma.

Personal dose measurements were carried out in about 100 selected settlements with varying Cs ground contamination of from less than 74 kBq/m^2 to about 3700 kBq/m^2. In some of these settlements decontamination measures had been previously taken. The settlements also varied owing to size and economy (agricultural, industrial).

The dosimeter was a tissue equivalent LiF thermoluminescence detector of the type TLD-100. It was distributed together with an information sheet and a questionnaire for statistical reasons.

The measurement of the personal dose was carried out in summer 1992 and in 1993 between May and September. A supplementary measuring campaign took place in winter 1993/1994. In 1993, every person being monitored received a second dosimeter to determine the area dose rate in their home.

Figure 2 shows the correlation between person-related dose rate and soil contamination for the 1992 and 1993 measurements. The deviation of the values for high soil contamination is to be attributed to decontamination measures, since the contamination values specified apply to the original contamination prior to decontamination. The regression lines in Fig. 2 allow an estimate of the personal dose equivalents to be made.

The effective dose equivalents estimated are compiled in Table III for a soil contamination of 1 kBq/m^2. The contribution from natural radiation exposure was not taken into consideration. The effective dose equivalents in lines 1 and 2 were

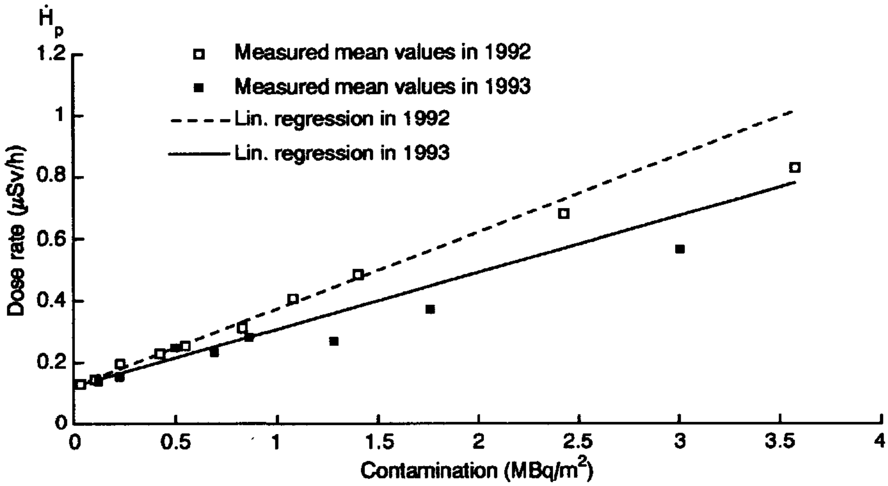

FIG. 2. Correlation between the person-related dose rate $\dot{H}_p$ and the soil contamination in villages.

TABLE III. COMPARISON OF EFFECTIVE DOSE EQUIVALENTS DETERMINED ACCORDING TO DIFFERENT METHODS FOR A SOIL CONTAMINATION OF 1 kBq/m^2

Line	Method	Year	Dose rate (μSv/a)
A	**From the area dose rate**		
1	Assuming 0.92 μGy$\cdot$h$^{-1}\cdot$MBq$^{-1}\cdot$m^{-2}, from Ref. [2]	1991	2.52
2	German measurements over pasture (1.1 μSv$\cdot$h$^{-1}\cdot$MBq$^{-1}\cdot$m^{-2})	1992	2.66
B	**From soil contamination**		
3	Official method of the State Committee for Hydrometeorology	1991	3.51
C	**From individual dose measurements**		
4	Institute of Radiation Hygiene	1991	2.10
5	TLD for villages (German measurements)	1992	1.62
6	TLD for villages (German measurements)	1993	1.34
7	TLD for towns (German measurements)	1992	0.77

calculated from measured area dose rates with consideration of shielding and stay-time factors inside houses. The effective dose equivalent in line 3 is calculated from the soil activity according to the official method of the State Committee for Hydrometeorology in Russia with a derived area dose factor ADF = 0.13 $mSv \cdot km^{-2} \cdot Ci^{-1} \cdot a^{-1}$. Line 4 is based on personal dose measurements by the Institute of Radiation Hygiene, St. Petersburg [2], and the effective dose equivalents in lines 5 and 6 are derived from Fig. 2.

As was to be expected, there is not complete agreement between the effective doses calculated according to the different methods. The values derived from the area dose rate are higher than those from personal dose measurements. It should be noted that the calculation of the effective dose from the area dose rate was based on some very generalized assumptions. The values derived from personal dose measurements should be most reliable, since they take precise account of the presence of persons at differently contaminated locations.

TABLE IV. ANNUAL DOSE IN 1993 AND TEN-YEAR DOSES FOR ADULTS IN SETTLEMENTS WITH THE HIGHEST BODY ACITIVITIES MEASURED IN 1991-1993

Village	District	Int. dose (mSv/a)	Ext. dose (mSv/a)	Ten-year int. dose (mSv)	Ten-year ext. dose (mSv)	Ten-year total dose (mSv)
Cheremel	Rovno	2.3	0.1	104	1	105
Veshiza	Rovno	2.2	0.1	92	1	93
Kirov	Gomel	2.2	1.9	90	34	124
Staroye Selo	Rovno	1.8	0.1	72	1	73
Drosdyn	Rovno	1.7	0.1	70	1	71
Unecha	Klincy	1.3	0.7	51	11	62
Veprin	Klincy	1.5	1.3	62	21	83
Beresovka	Klincy	1.3	0.3	53	5	58
Sarechye	Klincy	1.3	0.5	53	9	62
Tulukovchina	Klincy	1.1	0.5	46	10	56
Uvelye	Krasnaya Gora	1.1	0.6	46	29	75
Verbovka	Rovno	1.0	0.1	41	1	42
Saborye	Krasnaya Gora	1.0	3.1	41	56	97

5. DOSE ASSESSMENT

5.1. Actual dose

The dosimetric evaluation of the measurements is given in Table IV for the villages with the highest average body activity in 1993. On the assumption that the caesium body burden is constant over the whole year, an ingestion dose factor of 0.04 mSv/kBq·a for adults of >20 years applies.

Further, Table IV presents the results of the external dose calculation for the mean soil contamination of each village. According to Table III the calculation of the external dose equivalent from soil contamination was performed applying the area dose factors measured with TLDs.

The highest current total doses were found in Kirov in the Narovlya district. This is a settlement near to a forest, with a high degree of self-sufficiency. In the Rovno region, internal doses are high and the external doses are low because soil contaminations are low.

The ICRP dose limit for the general population of 1 mSv/a is exceeded in most of the villages given in Table IV, but in no case the dose limit for translocation (5 mSv/a) was reached. All results are given for adults. For children the doses are in the same range because, in general, they had significantly lower contamination. This compensates the higher biological sensitivity.

5.2. Dose reconstruction

The external dose reconstruction makes use of the fact that the decrease in the dose rate of the $^{137}Cs/^{134}Cs$ mixture due to physical decay, considering the higher area dose factor for ^{134}Cs, for the ten-year period since 1986 is about 65%; in the first year it is 18% and in the tenth year 4%. In addition, migration effects must be considered. Our measurements in 1992 over undisturbed ground yielded a mean value of 0.69 nGy/h over soil contaminated with 1 kBq $^{137}Cs/m^2$. This is a reduction of 63% compared with the 1986 value of 1.82 nGy/h given by Russian scientists [2]. Thus, migration effects are of the same order of magnitude as physical decay. For our calculation we considered all these effects, with the consequence that the annual dose in 1993 resulted in an 18 times higher ten-year dose.

The reconstruction of the ten-year internal dose on the basis of our whole-body counter measurements needs some knowledge about the development of the activity level in humans during the first few years after the accident. Results from Russia and Belarus [3] reveal a decrease by a factor of 10 from 1986 to 1991. But, unfortunately, this information is uncertain because of the fact that the measurements were not carried out systematically over the years and with the same persons. Therefore, the variation for these results is great.

Systematic monitoring of a fixed group of persons over the first few years after the accident was performed in Germany. After an initial dose increase in 1986, an exponential decrease was observed since 1987, with a factor of about 20 for the first five years (1991). Considering the fact that the contamination and the lifestyle in rural German areas such as Berchtesgaden seem to be more similar to those in urbanized Russian areas, we suggest for dose reconstruction purposes for towns in the CIS a decrease by a factor of 20 from the end of 1986 to 1991. For villages we suggest a decrease by a factor of 15 from the maximum at the end of 1986 to 1991, which is between the German experience and the experience in Belarus.

In Table IV the results of the ten-year dose equivalent for external and internal doses are listed for those villages and towns of the three republics which had the highest mean body activities. The highest ten-year total dose is 124 mSv. This value does not represent any acute health risk and is below the ICRP dose limits for persons professionally exposed to radiation.

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THE CHERNOBYL SASAKAWA HEALTH AND MEDICAL CO-OPERATION PROJECT

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The Chernobyl Sasakawa Health and Medical Co-operation Project was launched in May 1991, and we expect to accomplish medical screening of more than 150 000 children, residing in five areas of Belarus, Russia and Ukraine, by the end of April 1996 — the end of our five-year plan. As far as I know, this project is the largest screening programme of children living in the contaminated areas. It has been introduced in issue No. 16 of the DHA News — the official bulletin of the Department of Humanitarian Affairs of the United Nations.

The project was originally conceived as a response to the request from the former USSR Government in 1990. When the late Ryoichi Sasakawa, the founder of the Nippon Foundation and of the Sasakawa Memorial Health Foundation, received this request, his first question was how Japan could best help the people in the affected areas who were still suffering from the aftermath of the accident, utilizing especially the experience from Hiroshima and Nagasaki. The request was first addressed to the Nippon Foundation, which is well known as a leading private financial contributor to the WHO, but the planning and implementation of the project was entrusted to the Sasakawa Memorial Health Foundation, which has wide experience in international health and medical co-operation in such fields as leprosy, parasite and Aids control.

To assess the situation and the magnitude of the problems in connection with the Chernobyl accident, such as the levels of radioactive contamination, and the past or planned relief activities, the Sasakawa Memorial Health Foundation sent several groups (the first one in August 1990), composed of Japanese medical experts engaged in various medical research activities related to the Hiroshima and Nagasaki atomic bombs, to the affected areas. They reported that great psychological uncertainty and fear was prevalent among the people, due in part to lack of dissemination of accurate information, and that it was essential to determine the actual state of the effects of the accident.

In view of this, Ryoichi Sasakawa felt that it was most crucial to eliminate the unnecessary fear of parents, particularly mothers. Thus, the goal of our mission was to carry out medical screening of children so as to give accurate information to the parents on the health state of their children, since it is children who are most susceptible to the effects of radiation. Another important element in focusing on children is that they represent our hope for the future. The fundamental concept of the co-operation in this project was to find out what can be done today to build a better future, which was one of the underlying objectives of the Nippon Foundation and the Sasakawa Memorial Health Foundation.

Although the project was originally launched by the USSR and Japan as a joint endeavour to help the victims of the Chernobyl disaster, after the political upheaval in the summer of 1991 it became a collaborative work including Belarus, the Russian Federation, Ukraine and Japan. It should be noted that, fortunately, the political changes did not alter the running of our project, since our plan from the beginning had been based on a decentralized policy, i.e. the agreement was made between the Foundation and local centres, not with the Government of the former USSR.

The aims and the structure of the project can be summarized as follows:

(1) The aims of the project are scientific as well as humanitarian. It is our fundamental belief that a truly humanitarian act of this kind needs to have a solid scientific foundation.

(2) The main activity of the project is the medical screening of children living in the affected areas, and the provision of reliable and accurate information on the screening results to those examined. If any abnormal findings are detected in children, they receive follow-up examinations until a final diagnosis is made. It is imperative, therefore, that the first screening be carried out with the utmost accuracy and precision.

(3) The quality and reliability of the data obtained from the screening must be high in order to avoid misinterpretation. Therefore, standardization of the screening procedures and various examinations are of crucial importance. State-of-the-art medical equipment is being employed in the screening. In order to obtain standardized data from the five centres, continuous efforts have been made, by training of people and quality control, to maintain optimal conditions regarding the screening staff, medical equipment, reagents and supplies.

(4) The data obtained from the screening activities are of value for the future of humankind. Thus, the management of data is an important aspect of the project. One of our next targets of data analysis will be to examine the internal and external effects of radiation at the time of the accident on the health of children.

Since the territories contaminated by the Chernobyl accident are vast and more than four million people resided in these areas, we established five collaborating centres around Chernobyl, which were to become the bases of screening activities: the Mogilev and Gomel centres in Belarus, the Klincy centre in Russia, and the Kiev and Korosten centres in Ukraine. These centres were provided by the USSR Ministry of Health.

The project activities include: (1) the provision of five diagnostic mobile units equipped with highly advanced thyroid ultrasound instruments, a haemo-analyser, a whole-body counter, etc.; (2) the establishment of five centres equipped with the same items as those with which the mobile units are equipped; (3) the provision of medical equipment and supplies; (4) the continuous supply of medical reagents; (5) sending of Japanese experts to the centres; (6) training of medical staff of the centres on site and in Japan; and (7) health education of the residents of the affected areas.

The subjects of health examination are children born between 26 April 1976 and 26 April 1986 (age the time of the accident: 0–10 years); 146 490 children have been examined in the period from 15 May 1991 to 31 December 1995. The data obtained from 84 000 of these children (up to 31 December 1994) were analysed and used for further evaluation [1].

The course of health examination, either at a mobile diagnostic laboratory or at a centre, includes: collection of the disease history and biographical information; collection of anthropometric data; measurement of the whole-body ^{137}Cs radiation dose; ultrasonography with quantitative measurement of the thyroid; and blood sampling for further analysis. All information obtained is processed at each centre and then entered into a database at the Mogilev centre.

Since 1991, we have organized a workshop and a symposium every year at the five centres, involving the Ministries of Health of the three States, to review the past achievements and to determine the next steps. With these efforts, the quality control of the examination data and the information of individuals have indeed improved from year to year, and the data accumulated to date provide an invaluable database for future analyses. Other accumulated material, such as blood smears, serum samples, thyroid images stored on magneto-optical disks and information on the whole-body ^{137}Cs dose, also play an important role in both retrospective and prospective studies. So far, no relationship has been found between the occurrence of childhood thyroid diseases and haematological disorders and the whole-body ^{137}Cs (Bq/kg) levels/soil ^{137}Cs contamination levels (Ci/km^2). All health examination data have been published in English and Russian in annual reports since 1992. The whole-body ^{137}Cs counting data are published in Refs [2, 3], and a summary of the four-year examination, including haematology, dosimetry and data processing, is published in Ref. [1]. The thyroid findings are reported in Refs [4–10]. Another publication is a Russian/English textbook, the Chernobyl Sasakawa Radiation Science Series [11–13].

The Japanese projects, including our own, which started as humanitarian assistance to children and other inhabitants of contaminated areas, have gradually become to play an important role in the realm of scientific analysis;we hope that the results can be used not only in cases of acute radiation-induced disorders but also in handling problems of leading a safe life in the areas with the worst radioactive contamination in the history of humankind.

Some other major organizations in Japan are concerned with the Chernobyl accident and have contributed to the projects: the Japanese Ministry of Foreign Affairs, the Radiation Effects Research Foundation, the Hiroshima Red Cross and Atomic Bomb Hospital, the National Institute of Radiological Sciences, the

Hiroshima University, the Nagasaki University, the Hiroshima International Council for Health Care of the Radiation Exposed, and the Nagasaki Association for Hibakusha's Medical Care. The Japanese Government provided approximately 20 million US dollars to the WHO, for medical equipment and supplies for the WHO International Centre on Radiological Issues in Obninsk, Russia, which was a major organization promoting the WHO International Programme on the Health Effects of the Chernobyl Accident, to contribute to the mitigation of the health consequences for the affected people.

Since the main characteristic of radiation injury is 'late effects', long-term follow-up studies as well as efforts to prevent the scattering of data need to be continued to ensure the effective use of the data. Strong attention should be focused on the need for early diagnosis and prompt treatment of individuals in the high-risk groups.

In conclusion, I wish to stress that all the data obtained, including those of our own project, should be globally shared and analysed, so that the lessons to be learned from the Chernobyl accident can be of benefit to all.

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RADIOGENIC HEALTH EFFECTS OF THE CHERNOBYL ACCIDENT: INITIATIVES OF THE UNITED STATES OF AMERICA IN COLLABORATION WITH BELARUS, THE RUSSIAN FEDERATION AND UKRAINE

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1. INTRODUCTION

This presentation reviews primarily research activities supported by the United States Department of Energy on the health effects of the Chernobyl accident. Several United States Government Chernobyl initiatives are co-ordinated by the US Department of Energy, whose responsibilities include safeguarding our nuclear weapons arsenal, cleaning up old nuclear production facilities and promoting energy development in the United States of America. Until the end of the Cold War, the principal task of the Department was the production of nuclear weapons. Starting in 1991 the US Department of Energy re-focused its mission on safeguarding and dismantling the US nuclear arsenal, disposing of radioactive materials and cleaning up nuclear and hazardous wastes. The Department also devotes substantial resources to energy research. A critical component of the Department's mission is protection of the health and safety of workers, the public and the environment. The Department created its Office of International Health Programs to expand these activities to the international arena — the Marshall Islands, Japan, Spain and the States of the former Soviet Union.

2. INITIATIVES IN CHERNOBYL

The United States' response to the 1986 Chernobyl accident has included humanitarian aid, technical assistance in the nuclear and fossil energy sectors, and ongoing scientific studies of health impacts. The US Department of Energy recently initiated several nuclear safety related activities at Chernobyl. The Department is providing equipment that will enhance fire protection and is helping the plant to establish a quality assurance programme that meets all applicable nuclear standards. Another project will help implement training programmes for operational and maintenance staff. The US Department of Energy will provide an analytical simulator for the Chernobyl site to augment this training. Additionally, we are transferring methods for developing symptom-based emergency operating instructions, drawing on the US experience at Three Mile Island. A safety parameter display system is also being provided. In the area of nuclear safety research and development, the Department is working with Ukrainian authorities to establish an International Research Center on Nuclear Safety, Radioactive Waste, and Radioecology in Slavutich near Chernobyl. The Center will be a vehicle for international collaboration on nuclear safety. This initiative can help avoid duplicative work and can leverage research and development dollars through joint funding.

In addition to nuclear reactor safety, the US Department of Energy is engaged in extensive health-related activities in Chernobyl. One initiative overseen by the Department, under the auspices of the Joint Co-ordinating Committee on Civilian Nuclear Reactor Safety (JCCCNRS), is the study of the environmental transport of released radionuclides and the long-term health effects of their release. In 1990 the JCCCNRS Working Group 7 began to focus on the epidemiology of human health impacts (thyroid disease, leukaemia, ocular radiation effects) and on related dose reconstructions. The following is a brief review of US-funded research projects relating to the health effects of the Chernobyl accident. Almost all projects are sponsored by the US Department of Energy in conjunction with the Nuclear Regulatory Commission and the National Cancer Institute. An inter-agency agreement gives the USA lead to the National Cancer Institute to develop and implement several of the scientific protocols.

2.1 Thyroid studies

At the National Cancer Institute, Dr. Bruce Wachholz co-ordinates a group of US scientists who are working with counterparts from Belarus and Ukraine on two epidemiologic studies. The research focuses on thyroid diseases in persons who were children at the time of the accident. These cohort studies are currently in their first year and we hope to be able to continue them for 15 to 30 years.

2.1.1. Belarus-USA Thyroid Study

The scientific protocol to study childhood thyroid cancer and other thyroid diseases was signed in May 1994. Dr. Nicola Krisenko, the Deputy Minister of Health in Belarus, serves as Project Director for this study. The cohort consists of 15 000 individuals who were less than 18 years old when the accident occurred and had the radiation dose to the thyroid gland recorded at that time. These individuals will receive complete diagnostic thyroid examinations. The results of these examinations, together with data from dose reconstructions, will be used to evaluate the relationship between the radiation dose to the thyroid, the age at exposure and the incidence of thyroid disease. A data co-ordinating centre and a clinical laboratory have been established for this study. Scientists from the USA and Belarus expect to initiate screening of the cohort soon.

2.1.2. Ukraine-USA Thyroid Study

The US Department of Energy supports a similar long-term epidemiologic study in Ukraine. The research protocol was signed in May 1995. The National Cancer Institute has taken the lead in working with Professor Nikolai Tronko of the Ukrainian Medical Institute and other Ukrainian scientists to implement this protocol. Like the thyroid study for Belarus, the primary objective of the Ukrainian study is to estimate the risk of thyroid disease as a function of dose and age. This study will focus on a cohort of about 70 000 individuals all of whom were under 18 years of age when the accident occurred and had the radiation dose to the thyroid measured at that time. Both the Belarus thyroid study and the Ukraine–USA thyroid study will be reviewed by binational oversight groups consisting of ten members, five named by the authorities of Belarus or Ukraine and five named by the USA. These groups will oversee the studies to ensure the highest scientific standards. We look forward to having the oversight groups fully implemented in the near future.

It is our hope that these two thyroid studies will complement other work currently supported or planned by the European Union and other organizations. We expect that these studies will significantly add to our understanding of the risk and the aetiological basis of radiation-related thyroid disease in children.

2.2. Leukaemia and other haematologic diseases among clean-up workers

In addition to the two projects on thyroid disease, the US Department of Energy, the Nuclear Regulatory Commission and the National Cancer Institute support efforts to design a scientific protocol to examine the incidence of leukaemia, lymphoma and related blood disorders among Ukrainian liquidators. Dr. Gil Beebe of the US National Cancer Institute and Dr. Anatoly Romanenko of the Ukrainian Research Center for Radiation Medicine have been working with scientists from Ukraine and the USA to prepare the protocol for this study. The Institut de protection et de sûreté nucléaire of the Commissariat à l'énergie atomique of France has agreed to take part in this project as well. The study will focus on leukaemia, lymphoma and related disorders. The aim of this study is to expand the present knowledge of the dose–response relationships in the moderate and low-dose regions, of the time–response functions, and of the pathogenesis and molecular biology of leukaemia especially. This study will begin shortly.

2.3. The Ukraine–USA Chernobyl ocular study

Finally, the Department of Energy is the US sponsor of a study investigating radiation-induced cataract formation in Ukrainian liquidators. The goal of this study is to determine whether cataract formation is a stochastic response or a threshold response to radiation. Studies of a cohort of 12 000 liquidators will be carried out using a nested case-control analysis to assess the distribution of radiation-induced cataracts as a function of dose. This is the largest study ever conducted of radiation-induced lens opacities in a population with measured radiation exposure. The study is headed by Professor Basil Worgul of Columbia University, Professor Ilia Likhtarev of the Ukrainian Scientific Centre for Radiation Medicine, and Academician Yuri Kundev of the Kiev Institute for Occupational Health.

3. CONCLUSIONS

In conclusion, the US Department of Energy as well as the Nuclear Regulatory Commission and the National Cancer Institute are committed to working with the international scientific community to support epidemiologic health studies related to the Chernobyl accident. We expect that the results of these studies will greatly enhance our understanding of the risks associated with exposure to ionizing radiation. At the US Department of Energy we are the facilitators of this important work. In carrying out our mission, we are committed to: (1) increasing co-ordination among the international agencies that fund radiation health studies related to the Chernobyl accident, (2) ensuring that support is provided to the best projects and the best scientists and health professionals, and (3) expanding co-operation among scientists working in the field of radiation health effects. We need to be mindful that the federal budget of the USA is in the middle of a cycle of contraction. The budget cuts at the Department of Energy have been particularly severe. The budget of the Office of Environment, Safety and Health, which supports the Chernobyl programme, has been reduced by 25% since 1993 and is likely to decline further in the near future. We are committed to completing this important work despite the political and economic obstacles. However, the budget cuts in Washington may impact our ability to fund these studies at the level we would like. We will need to find innovative methods — including obtaining budgetary contributions from other federal agencies and perhaps other countries — to fund these studies properly in the future. We all share common goals — to enhance our understanding of the risks associated with exposure to radiation, to help the survivors, to protect the surrounding areas, and to ensure that such an accident will never ever happen again. The US Department of Energy is looking forward to working with all of you, to co-ordinate our efforts and to leverage our resources, so that together we can accomplish these important goals.

TECHNICAL SYMPOSIUM

TOPICAL SESSION 1

Clinically Observed Effects

Chairperson	F. METTLER, United States of America
Scientific Secretary	G. SOUCHKEVITCH, WHO
Rapporteur	G. WAGEMAKER, EC
Expert Committee	V. BEBESHKO, Ukraine N. GRIFFITHS, France A. GUSKOVA, Russian Federation N. KRISHENKO, Belarus

CLINICALLY OBSERVED EFFECTS IN INDIVIDUALS EXPOSED TO RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT

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Abstract

CLINICALLY OBSERVED EFFECTS IN INDIVIDUALS EXPOSED TO RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT.

Accidents in the nuclear energy and fuel reprocessing industry have caused clinical effects in workers who were accidentally exposed to high doses of radiation. Such high dose exposures acutely and severely affect blood cell production, resistance against infections and intestinal function, and may result in severe damage to the skin. The complex disease which originates from such exposures is known as acute radiation sickness (ARS). The most common symptoms of ARS are initially nausea, vomiting and diarrhoea and, later on, bleeding and generalized infections. If untreated, ARS is lethal, even for radiation doses that are not necessarily incompatible with survival of the human organism and which are regularly used in clinical medicine to treat some forms of cancer. After a nuclear or radiological accident, radiation damage is frequently complicated by other injury, such as thermal burns. The Chernobyl accident resulted in an unprecedented total number of 237 individuals who were suspected of suffering from ARS. All patients had been exposed either as personnel at the reactor or as liquidators (rescue workers) in the first days after the accident. The diagnosis was confirmed in 134 cases. Of these, 41 had mild (Grade I) ARS; one additional patient is still disputed; all survived. Fifty patients had Grade II ARS, of whom one died. Seven patients out of 22 with Grade III ARS died. Of the most severely affected 21 patients, who suffered from Grade IV ARS, all but one died despite intensive treatment. Among the Grade IV ARS patients, gastrointestinal damage and radiation skin burns were the most common complicating factors. In the last ten years, nine of the ARS patients and five of the non-confirmed cases have died. Their deaths do not relate to the original severity of ARS and are, in the majority of cases, probably not directly attributable to the radiation exposure. To improve care for the victims of such exposures, a number of issues need to be addressed, such as: the reasons for the failure of the treatment of bone marrow transplantation made available to the most severely affected patients; immediate diagnosis and alternative modes of treatment; the best strategy for the medical management of the acutely exposed radiation accident victim in the future in view of new developments; and the quality of life of the surviving patients. It was realized almost immediately that from the medical point of view the persons acutely exposed as a result of an accident on this scale are difficult to manage, since specialized centres have a capacity for only a few patients. The experience gained from these patients has provided additional information about the mechanisms of acute radiation injury. There are many uncertainties about the prospects of the survivors. Medical care at a competent level should be provided for these patients for many years to follow, preferably co-ordinated by a single highly qualified centre, while research efforts should focus in particular on treatment regimens in the acute phase which anticipate the health complications that will necessarily follow.

1. THE ISSUES

When acute radiation doses to the tissues of which a mammalian organism is composed are large enough, there may be a partial or complete loss of function. In extreme cases, there may be complete tissue death. If the tissue is vital, it may result in death.

There have been many accidents with radiation sources that have caused serious local injury, sometimes calling for the amputation of limbs. Some accidents have caused more general exposure of the whole body and have led to death. Of those accidents affecting members of the public, most have been due to loss of radiation sources used in industry, usually in industrial radiography. Some have resulted from the improper disposal of large sources used in medicine. A few accidents in the nuclear energy and reprocessing industry have caused clinical effects in workers, among them the victims of the accident at the Chernobyl plant, who were accidentally exposed to high doses of radiation.

Such high dose exposures acutely and severely affect blood cell production, resistance against infections and intestinal functions, and may result in severe damage to the skin. The complex of disease symptoms which originate from such exposures is known as 'acute radiation sickness' (ARS). The most common symptoms of ARS are initially nausea, vomiting and diarrhoea and, later, bleeding and generalized infections with high fever, often caused by micro-organisms that are normally not harmful. In an accident situation, the radiation damage is frequently further complicated by other injury, such as thermal burns.

The Chernobyl accident on 26 April 1986 resulted in an unprecedented simultaneous number of 237 persons with signs of ARS, of which 134 were confirmed as ARS cases and treated, and 28 died, despite the rapid deployment of emergency intensive medical care in a specialized and highly experienced centre. An additional two individuals had died at the accident site, bringing the number of fatalities at the plant to 30. (Another person died apparently from a coronary thrombosis, not at the plant site.) The other cases have become known as 'not confirmed cases of ARS'. Among the patients, 56 had severe radiation inflicted skin injury, and two had in addition thermal burns. Nearly half of these (26 out of 56) were among the 28 who died.

On the basis of symptoms, ARS is classified into four categories of severity, Grade I (mild) to Grade IV (severe). A breakdown of the Chernobyl cases by outcome and by severity of ARS is given in Table I. Essentially, for the hospitalized cases, the picture is clear with respect to: the doses of radiation; the developing symptoms of ARS; the adequacy of medical care given at the time; the causes of death in the acute phase; the medical treatment given in the recovery phase to the survivors; and the causes of additional deaths in the ten years that have elapsed since the accident.

TABLE I. DISTRIBUTION OF PATIENTS TREATED FOR ARS IN 1986 BY OUTCOME AND BY GRADE OF ARS

Total number of patients		237
Survivors of acute phase		209
Died in acute phase (1986)		28
Survivors (to February 1996) of the acute phase		
ARS	Grade I (mild)	41[a]
	Grade II	49
	Grade III	15
	Grade IV (severe)	1
ARS	not confirmed	103
Total		209

[a] One further case is still disputed; included here under 'ARS not confirmed: 103'.

To improve medical care for victims of such an accident, a number of questions need to be answered:

— Why did the therapy of bone marrow transplantation, at the time thought to be the treatment of choice for the high dose patients, fail?
— Are alternative modes of treatment available, and what would the best strategy for the medical management of the acutely exposed radiation accident victim in the future?
— Which diagnostic tools have become available to enable a rapid estimate of the radiation damage, a solid prognosis and tailored treatment?
— What is the quality of life of the surviving patients, and what can be done to improve their well-being?
— Which health consequences are presently predictable from previous accidents and experimental studies and what can be done to prevent or alleviate incapacities?
— What is the likelihood of unexpected health consequences for the exposed persons, given the scientific advances made in the past ten years?
— What did we learn from the accident in terms of insufficient medical knowledge to manage accidental exposures?

The experience gained from the study and treatment of these patients has provided additional information about the mechanisms of acute radiation injury.

2. BACKGROUND SCIENTIFIC KNOWLEDGE

There is a substantial body of knowledge about the early clinical effects of radiation. Much of this has come from experimental studies in rodents and non-human primates, which has had an impact on the current practice of radiotherapy, for example, and has also resulted in the clinical treatment of malignancies by whole body irradiation followed by bone marrow transplantation. The present insights into blood cell production, immunological reactions and diseases, and advances in transplantation biology are not well thinkable without the studies directed at the consequences of partial or whole body irradiation. As a consequence, tens of thousands of patients have been irradiated for medical reasons with whole body doses similar to or higher than those received by the Chernobyl patients. Although this practice is still relatively young and is awaiting full evaluation in the forthcoming decade, it has resulted in significant knowledge on the responses of the human body to doses equivalent to a single exposure of up to 10 Gy.

Acute radiation effects as well as organ damage originate from cell death in vital organs. Cell death by itself is not necessarily life threatening, as it is a natural process, while many organs are capable of regeneration or are not functionally affected by the loss of even a substantial number of cells. However, if killed cells are not sufficiently replaced, at the tissue level the effect appears to be 'deterministic' in nature: the level of the absorbed radiation dose determines whether a clinically observed effect will occur. The severity of the effect is directly related to the radiation dose, with steep dose effect relationships above the threshold dose below which the effect does not occur. This is opposed to so-called 'stochastic' effects, such as tumour induction, which is based on gene damage, for which the probability of being detrimental increases with radiation dose. No certainty exists with respect to the development of a pathological condition which becomes clinically manifest.

The sensitivity to ionizing radiation is not equal for all cells in the body. Cells from systems that divide rapidly are in general more sensitive than cells in a quiescent state. Cells that have a high sensitivity include: immature bone marrow cells, which produce blood cells daily in large quantities; the cells lining the intestinal tract, which similarly have to be replaced naturally at a high rate; and lymphocytes. Cells with slightly less sensitivity include those of the eye lens and the linings of the mouth, oesophagus and skin. Cells of intermediate sensitivity are those of the liver, kidneys, lungs, thyroid and fibrous tissue. Connective tissue, bone, cartilage and neuronal tissue have a low sensitivity to radiation, while cells that do not have a nucleus, such as red cells and blood platelets, are, for all practical purposes, not sensitive at all to doses incompatible with survival of the whole human organism.

With increasing doses received over a short period of time, not only will increasing numbers of cells be killed but, at doses higher than the threshold dose, a number of organ functions will become impaired or disabled. The most sensitive vital function is blood cell production. However, the most rapid effects (at absorbed radiation doses which do not cause lethal brain damage) are lymphocyte death, destroying the immune system, and damage to the gastrointestinal tract, resulting in loss of a physical barrier against invading micro-organisms as well as a much impaired capacity to digest and absorb food and to maintain a fluid and electrolyte balance. In addition, destruction of the capacity to produce blood cells will result in severely reduced numbers of white cells, causing a loss of the defence against micro-organisms within a matter of days, as well as a loss of blood platelets within slightly more than a week, resulting in an increased tendency to bleed.

2.1. Radiation damage to bone marrow

Blood contains cells that are involved in oxygen and carbon dioxide transport, the defence against micro-organisms and blood clotting. As most of the blood cells are short lived, their perpetual production from immature cells in the bone marrow is necessary. These immature cells are the most radiation sensitive vital cells of the human organism, radiation exposure rapidly resulting in cessation of blood cell production. Blood cell production (or haemopoiesis) is maintained from a small number of so-called stem cells, which reside in the bone marrow and generate some

1011 or about 100 g of new blood cells daily. As bone marrow stem cells are readily transplantable if injected into the blood stream, donor bone marrow transplantation has long been considered the treatment of choice for the severely injured radiation accident victim who has undergone whole body irradiation.

Donor (or allogeneic) bone marrow transplantation has several risks. For acceptance of all types of transplants, the immune functions of the recipient need to be suppressed to prevent the immune cells (the lymphocytes) of the recipient from recognizing the graft as 'foreign' and launching an immune attack. In the case of bone marrow transplantation, the immune suppression required is extreme compared with that in the case of kidney and heart transplants, for instance. In clinical medicine, such an immunosuppression can only be achieved by relatively high doses of homogeneous whole body irradiation. However, in radiation accidents, exposures are always heterogeneous, which means that some of the circulating lymphocytes can escape death and may reject the graft. It has been calculated that even a 1000-fold reduced immune system still has the capacity to reject a donor bone marrow graft [1-2].

Bone marrow grafts are singular in that a significant proportion of the cells are similar lymphocytes, but are those of the donor. These cells may in their turn recognize the tissues of the recipient as 'foreign' and try to reject them. This reverse reaction is one of the characteristic and either lethal or disabling risks for recipients of bone marrow transplants. In the event of insufficient immune suppression of the recipient or insufficient removal of the immune cells from the graft, these cells can also recognize each other as foreign and start a deadly mutual attack, resulting in both rejection of the bone marrow graft and elimination of the residual stem cells of the accident victim. These mechanisms played a significant part in the failure of bone marrow transplantation in the Chernobyl recipients.

It has been recognized that immature haemopoietic stem cells are heterogeneous with respect to radiation sensitivity, the most immature stem cells, which are responsible for long term haemopoietic and immune reconstitution, being less sensitive to radiation than was previously thought on the basis of lethality data [3-5]. The recent reappraisal of the radiation sensitivity of immature haemopoietic stem cells [6-11], which was not recognized at the time of the Chernobyl accident, simply tells us that the bone marrow stem cells will ultimately regenerate the blood cell production tissues following radiation doses that are not otherwise incompatible with survival of the human organism.

Together with the discovery of quite a few physiological stimulators of blood cell production and their pharmaceutical availability by recombinant deoxyribonucleic acid (DNA) technology, this new finding will have consequences for the future treatment of victims of whole body irradiation accidents. It is likely that even following doses of exposure approaching lethality from gastrointestinal damage, sufficient numbers of haemopoietic stem cells will remain available for endogenous haemopoietic recovery, which means that the core of the treatment should be directed at abridging or shortening the period of shortage of blood cell production. Donor bone marrow transplantation with all its immunological hazards in the accidentally exposed individual will consequently be a less attractive choice.

2.2. Gastrointestinal function following accidental exposure to ionizing radiation

One major problem associated with treatment of patients following acute overexposure to ionizing radiation is the ensuing mixed pathology which at higher doses is a combination of effects on the haematopoietic and gastrointestinal systems. At higher doses, effects on the gastrointestinal system contribute significantly to the demise of the patient. Much clinical effort has been directed towards the restoration of haemopoiesis. However, although such an approach is not without some success, effective treatment of patients remains a serious medical problem because of the manifestation of gastrointestinal and indeed pulmonary complications.

Similar to haemopoiesis, the lining of the gastrointestinal tract needs to be permanently renewed from immature cells. This feature is considered a key factor in the high sensitivity to radiation of this tissue. In some ways, the understanding and treatment of radiation induced gastrointestinal and haemopoietic dysfunction may share common mechanistic approaches since, in both cases, the responses of the stem cell population are likely to be heterogeneous. Mechanisms classically defined as leading to acute gastrointestinal death are: decreased integrity of the lining, increased vascular permeability which results in excessive losses of fluid and electrolytes essential for maintaining circulation and life, the further destruction of the lining by bile, invasion of the defective lining by micro-organism, resulting in severe infections and alterations in blood flow and microcirculation [12–15]. All of these features must be taken into account with regard to immediate patient management.

In terms of acute exposure to ionizing irradiation, whether accidental or for medical purposes, two symptoms occur regularly: vomiting and anorexia. In the dose range of 0.5–1 Gy, anorexia may occur in 15–50% of patients [16]. In the dose range of 1–2 Gy, vomiting or retching will occur in 20–50% of the patients. To date, the precise mechanisms leading to anorexia or vomiting are unknown but are likely to be mediated in part by the central nervous system.

In one case of the use of a badly calibrated source (Riverside Methodist Hospital 1974–1976), it was noted that from one to three years following treatment some patients developed ulceration and/or perforation of the stomach and bowel [17]. This study is continuing in order to determine the longer term effects on the tissues and organs within the irradiated target mass.

Research into gastrointestinal physiology as such has increased greatly over the last two decades. The digestive system is complex and performs many integrated functions such as transport, absorption and breakdown of nutrients together with movement of water and electrolytes. In addition, this system is under neural, endocrine, immune and local hormonal control as well as control by luminal contents, all of which interact to orchestrate the various functions. It is also the largest immunocompetent organ of the body, and it is now evident that the epithelial cells as well as cells of the immune system play an important role in defence mechanisms against the intestinal micro-organisms [18, 19].

It is probable that, in part, ionizing radiation induces dysregulation of gastrointestinal function by effects on the synthesis, metabolism, release and actions of gastrointestinal hormones, neurotransmitters or locally released mediators. Modification of the functional capacity of one or several mediators may have profound effects on intestinal motility, absorption/secretion and host defence mechanisms. Furthermore, following exposure to ionizing radiation, the ensuing inflammatory response of this organ must be a major consideration with regard to patient treatment.

With regard to the scarce data available in the literature, gastrin plasma levels have been shown to decrease in the antrum of the stomach following radiotherapy for gastric carcinoma [20]. Recent work has demonstrated that ionizing radiation induces changes in plasma and tissue gastrointestinal regulators [20–26], which appear to depend on the dose of radiation received. These regulators include: gastrin releasing peptide, a neurotransmitter, which stimulates the secretion of gastrin and pancreas secretions; substance P and neurotensin, which, similar to gastrin releasing peptide, regulate gastrointestinal functions. Interestingly, the intestine is the richest source of substance P in the body and thus measurement of plasma levels may reflect disturbances in gastrointestinal synthesis and degradation. Of note also is that this agent has an important role in inflammatory responses.

The increases seen in gastrin releasing peptide following exposure to radiation may also be of physiological importance since this peptide is recognized as having an anorexic action. It has been well documented that irradiation markedly reduces food intake even at low doses. In a recent experimental study with non-human primates, at least three years after exposure, gastrin releasing peptide was found to be particularly augmented in the higher dose ranges. This may well correlate with the finding that the body composition of irradiated primates differs significantly from that of non-irradiated primates, in that irradiation makes these primates much slimmer.

It is thus possible that measurement of regulatory peptide plasma levels may be useful both as a diagnostic tool for radiation induced gastrointestinal dysfunction, given the apparent dose dependent increases in plasma levels, and to explain the physiology of the general gastrointestinal reaction to whole body irradiation.

To date, treatment of irradiated personnel with regard to gastrointestinal dysfunction has involved parenteral feeding and fluid/electrolyte replacement; and antibiotic/antiviral therapy together with antivomiting agents and antidiarrhoeal drugs. It is clear that therapeutic approaches should include not only appropriate patient maintenance with inhibition of injurious effects but also stimulation of the intestinal stem cell population in order to accelerate repopulation of the gut lining. It may also be required to continue treatment longer than previously thought necessary to limit long term effects. However, in order to improve at least palliative treatment, it is necessary to elucidate the primary causal factors, such as the extent of the inflammatory response and sequels, as well as to implement the new diagnostic tools which reflect gastrointestinal damage.

2.3. Radiation damage to the skin and underlying tissues

Skin reactions to high doses of radiation can be divided into acute and late effects. An acute reaction develops over the first few weeks, characterized by erythema, dry and moist desquamation, necrosis and apparent healing. The very early step of cell response, ranging from the first two hours to 2 days after irradiation, takes place before the appearance of any clinical lesion or during the first skin erythema, dependent on the delivered dose. It is characterized as an acute inflammatory response, accompanied by gene cascades which initiate the cellular response and as a consequence the tissue reaction. In this process the immediate release of a variety of cytokines apparently plays a key role which has, however, been insufficiently studied so far. Over the next months to years, atrophy, telangiectasia, fibrosis and chronic ulceration may develop, as well as carcinoma with a low frequency. A clinical classification, based on experience, has identified the grades of skin lesions developing as a result of acute local exposure (see Table II).

TABLE II. MAIN CLINICAL MANIFESTATIONS AND LEVELS OF ABSORBED DOSES (SHORT TERM GAMMA IRRADIATION) FOR DIFFERENT GRADES OF LOCAL RADIATION INJURIES TO THE SKIN

Phase development of local radiation injury	Grade of lesion and approximate dose			
	I 8–12 Gy	II 12–20 Gy	III 20–25 Gy	IV >26 Gy
Initial erythema reaction				
Time of appearance	Continues for a few hours, may be absent	Seen from a few hours to 2–3 days	Seen in everybody; duration from 3 to 6 days	Seen in everybody; severity does not decrease prior to manifestation of the main reaction
Main reaction				
Latent period	15–20 days	10–15 days	7–14 days	Absent
Clinical signs	Erythema, 'dry' desquamation	Erythema, oedema, blisters, desquamation	Erythema, pain, blisters, erosions	Oedema, pain, local haemorrhages/necrosis

Following an accidental exposure, the lack of accurate data on the radiation dose rate and exposure time precludes a reliable prognosis of the likely grade of local radiation injury (LRI). Thus the following methods are used to evaluate the possible grade of LRI, both in the acute and late periods, as well as to assess the effectiveness of methods of treatment.

(1) Observation of clinical signs (Table II);
(2) Calculations (dose rate, radiation source, geometry and other conditions of irradiation, duration);
(3) Modelling of the accident in different combinations;
(4) Electron paramagnetic resonance examination of patients' clothes in projection of exposure to the source of ionizing radiation.

On the basis of extensive experience, it has been concluded that for cases of exposure to doses of more than 20 Gy (Grade III–IV lesions), late radiation ulcers are likely to develop even where there is initial healing of acute lesions. Patients with Grade I lesions show full re-epithelialization with, at worst, skin scarring or atrophy. The majority of patients with Grade III lesions do, on the other hand, develop late ulceration. This confirms the necessity for early (20–30 days) surgical intervention after local irradiation with acute doses higher than 20 Gy. After such doses it is important to perform surgical intervention in the period of ulceration and necrosis to reduce the risk of the development of anatomical abnormalities and defects of damaged tissues.

For LRI of mild and moderate degrees (Grades I and II) experience has demonstrated that these cases can be treated using conservative approaches. Such conservative therapies are subdivided into general and local methods. It is the view of the Moscow group, which has treated the Chernobyl patients, that the most effective means of local therapy in cases of LRI, of severity Grade I–II, is the use of preparations giving the opportunity to use 'blister cover' as a natural barrier to secure against wound infection and to allow re-epithelialization of the eroded surfaces situated under the skin blister. In contrast to the haemopoietic and gastrointestinal system, the 'stem cells' of the skin, from which re-epithelialization originates, migrate only slowly and healing is therefore dependent on the surface area affected.

Radiation damage to the skin, apart from the cases of the Marshall Islanders and the victims of the radiological accident in Goiâna, Brazil, has received only limited attention by the medical scientific community. This is in part understandable owing to the fact that under the conditions of nuclear bomb detonations the sequelae of haemopoietic bone marrow depression as a result of total or near total body irradiation have to be considered the primary limiting factor for the survival of affected persons, both with regard to dose and to time. In nuclear power plant accidents, however, the situation is different, as contamination with non-uniform irradiation, including alpha and beta emitters, becomes more important.

3. DISCUSSION

3.1. Clinical signs and symptoms in the acute phase after the accident

The first information about the Chernobyl accident on 26 April 1986 was transmitted to the Ministry of Health of the USSR and directly to Clinic 6, Institute of Biophysics, in the first hours, from the local occupational medical facility of the Chernobyl nuclear power plant. First aid and transportation decisions were made during the first hours or within the first day. The measures were taken in close contact with the Clinic, which, as a centralized facility, had already examined hundreds of radiation accident patients from 1950 onwards (Fig. 1).

A total of 129 persons with suggested overexposure and possibly ARS were carried by air to the Clinic within the first 30 hours. The diagnosis was confirmed in 104 patients of this group. An additional 30 cases were established in Kiev later (from 108 suspected cases); one additional case is still disputed. The total number of patients and overall mortality data are given in relationship to the severity of ARS in Fig. 2 and Table I. The degree of severity and prognostic factors were based upon standard clinical laboratory data accumulated for accidents of the type in which total gamma exposure represents the major factor.

In the first week of hospitalization a lethal outcome was expected for 37 individuals. Ten of these patients survived, as has been reported in detail [27, 28]. Death appeared to be strictly related to dose (or severity of ARS) (Fig. 2). The majority

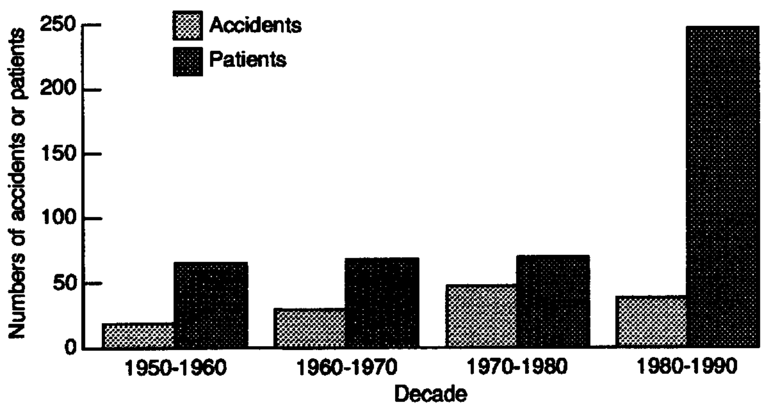

FIG. 1. Numbers of radiation accidents in the former Soviet Union and numbers of patients treated in The Institute of Biophysics for acute radiation sickness and local radiation injury. (Adapted from Dr. A.K. Guskova.)

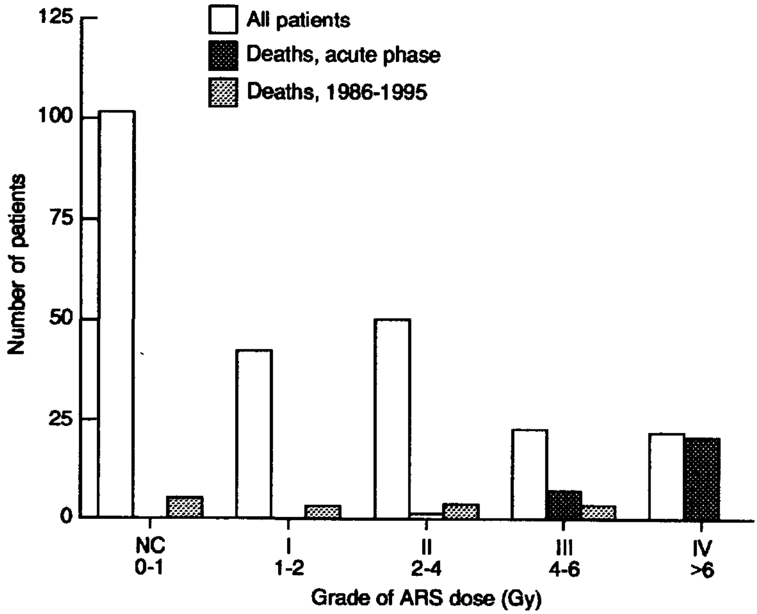

FIG. 2. Numbers of ARS patients and mortality following the Chernobyl accident. NC: diagnosis of ARS not confirmed. (Source: Dr. A.K. Guskova.)

of patients with a lethal outcome were among those that received whole body doses higher than 6 Gy. In almost all of these cases, there was combined injury due to beta exposure resulting in skin radiation injury, which had occurred in 56 patients and was more difficult to assess.

Other complicating factors were lung damage (pneumonitis), gastrointestinal damage and mucositis. The latter occurred in the vast majority of cases exposed to the three highest dose categories of Fig. 2. The gastrointestinal syndrome was a most severe problem in 11 patients who received doses higher than 10 Gy and resulted in early and lethal changes in intestinal function. In the range of 7–9 Gy, four out of six people showed symptoms of diarrhoea, and for doses of more than 11 Gy, all patients had diarrhoea with a more rapid time of onset [29, 30]. Treatment with fluid and electrolyte replacement and antibiotic/antiviral cover was unsuccessful in these cases.

The Chernobyl accident led to exposure with high amounts of beta irradiation (both contamination and incorporation), causing a clinical pattern of involvement which was different from the experience of Hiroshima and Nagasaki [29]. From the beginning, a striking feature was the large number of patients suffering from radiation induced damage of the skin and mucous membranes, especially of the

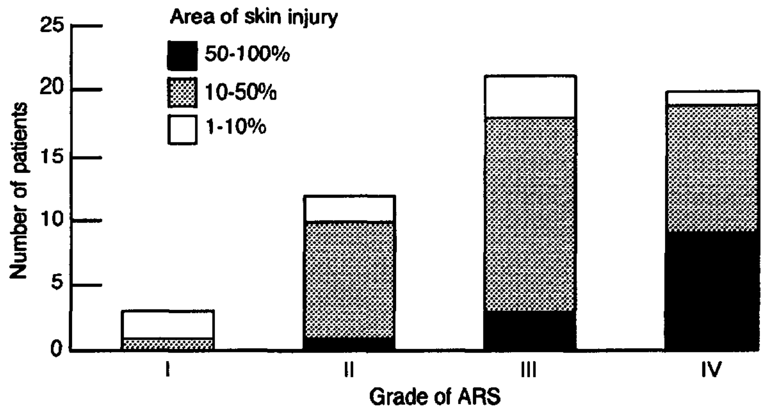

FIG. 3. Distribution of 56 patients with skin injury among 115 patients with ARS treated in Moscow, according to grade of ARS and extent of the area of skin injury. (Source: Dr. A. Barabanova).

upper digestive and respiratory tract, due to contamination by beta and gamma emitting isotopes, such as ^{137}Cs, ^{134}Cs and ^{90}Sr [30, 31]. Cutaneous lesions and/or oropharyngeal mucositis were the primary cause of death in the majority of patients who died as an immediate consequence of the accident [27].

Of the Chernobyl patients, 56 had radiation induced skin lesions of varying severity, not infrequently combined with radiation and thermal burns which were a significant clinical problem. The distribution of these patients in relation to the grade of ARS, and further subdivided according to the extent of skin damage, is shown in Fig. 3. This figure demonstrates that in general the more severe skin lesions were associated with the more severe cases of ARS. Lymphocyte analysis has subsequently shown that two of these cases had not received a total body dose sufficient to result in ARS [32]. However, the skin lesions in these two individuals (combined radiation and thermal burns) along with radiation induced skin lesions seen in a small group of liquidators were a significant clinical problem.

The victims of the Chernobyl accident who developed radiation injuries to the skin could be classified into four groups according to the following criteria: (i) the contribution of the beta and gamma radiation components to the total dose; (ii) the prevalence of distant or contact exposure to the skin; and (iii) the nuclide composition of the radioactive sources to which an individual was exposed. This classification was first published in 1990 [31]; however, the numbers of cases allocated to each group have been revised in the light of additional information and are given in Table III. The skin changes were in some cases so severe that they were not compatible with patient recovery, even in the absence of any ARS. The death of 26 patients in the first 3 months of the exposure was associated with skin lesions involving over 50% of the total body surface area (Table III).

3.2. Clinical signs and symptoms in the surviving patients

Those surviving acute radiation sickness have all been subjected to a traumatic experience with extensive physical injury and a long reconvalescence period up to the present time. Some of these people will bear the marks of their trauma for the rest of their lives, both in the psychological and in the somatic sense, just like the victims of other severe accidents. Although the extreme bone marrow suppression may have been resolved in a couple of months, full reconstitution of functional immunity may take at least half a year and normalization may not occur within years after exposure.

The latter feature does not necessarily mean that these patients have a functionally impaired immune system. Aside from the well known stochastic late radiation effects, the long recovery period for patients with severe skin injury, complicated by surgery and ill healing wounds, may cause chronic stress. Stochastic radiation effects are not expected before ten years after the accident, with the exception of leukaemia, which, however, has not been encountered among this group.

TABLE III. NUMBER OF DEATHS OVER THE ACUTE PERIOD AMONG THOSE ARS PATIENTS SHOWING SEVERE RADIATION INDUCED SKIN LESIONS AND NUMBER OF PATIENTS STILL ALIVE AFTER 10 YEARS

Grade of local radiation injury	No. of patients	No. of acute deaths	Alive after 10 years
I	17	1	14
II	6	4	2
III	6	6	0
IV	25	15	9
Total	54[a]	26	25

[a] Excluding two patients for whom lymphocyte analysis had shown that they had not received a total body dose sufficient to result in ARS.

It may in addition be expected that biochemical stress indices in these patients score high. In males, reproductive recovery may be very slow and in the higher dose ranges impaired fertility may be a lasting effect. Several components of the eye are rather sensitive to radiation, and patients may develop in particular cataracts, starting years after exposure. Quite some knowledge is available on late radiation effects, which is the subject of another paper. At high doses, cardiovascular and late gastro-intestinal problems may cause considerable discomfort. Consequently, many of the signs and symptoms given below fall within these general considerations.

To date, a detailed and scientifically sound overall account of clinical signs and symptoms of the surviving patients in the group of 237 is lacking in general. Also, confounding factors have not always been dissociated from possible radiation effects. However, fairly accurate information is available on certain subgroups. A group of 15 patients with the most severe skin lesions have been examined and treated in Munich and their present health status is well documented.

The clinical follow-up of ARS patients conducted in the clinical and laboratory departments of the Institute of Clinical Radiology in Kiev showed various mid-term and late effects. The patients who suffered from ARS and contracted skin lesions represent the most severely affected group of Chernobyl victims. The regional distribution of the 195 survivors is given in Table IV. Fourteen of the original 237 patients died in the follow-up period of 1986–1996; their deaths are not related to the degree of ARS. A list of causes of death of those that have died in the period of 1986–1995, most of these not necessarily as a consequence of the exposure to ionizing radiation, is given in Table V. It should be noted that this list lacks precision.

TABLE IV. LOCATIONS OF THE 195 SURVIVING PATIENTS[a]
(Data of February 1996)

ARS grade	Russia	Ukraine	Belarus	Azerbaijan	Kazakhstan
NC	3	93			1
I	3	36			
II	4	39	2	1	
III	3	9			
IV	1				
Total	14	177	2	1	1

[a] 237 patients, of whom 28 did not survive ARS and 14 died over the period 1986–1996.

TABLE V. ADDITIONAL DEATHS OVER THE PERIOD 1986–1995 AMONG THE PATIENTS SURVIVING ARS

Year of death	ARS grade	Disease recorded and/or cause of death
1986	NC	Car accident
1987	NC	Hypoplasia of haematopoiesis
1987	II	Lung gangrene
1988	NC	Encephalitis/encephalomyelitis
1990	II	Coronary heart disease
1992	III	Coronary heart disease
1993	NC	Sarcoma (thigh)
1993	I	Coronary heart disease
1993	III	Myelodysplastic syndrome
1994	NC	Coronary heart disease
1995	I	Lung tuberculosis
1995	II	Liver cirrhosis
1995	I	Fat embolism
1995	III	Myelodysplastic syndrome

Haemopoietic and immune system

During the period of observation, disorders of haemopoiesis were recorded in 40% of the persons with ARS and, similarly, abnormal numbers of immune cells (B and T lymphocytes) were frequently observed. These features may still reflect changes intrinsic to the recovery of the haemopoietic and immune system after a profound suppression in the acute phase. Several cases of myelodysplastic syndromes have been recorded and may be related to the radiation exposure; one patient who also had severe skin injury died recently from this disease.

Various diseases and work capacity

Gastrointestinal tract diseases increased, as did cardiovascular diseases, while respiratory diseases decreased. The frequency of diagnosed psychoneurological disorders has also decreased since 1986. However, 5–6 years after the accident there was a tendency of an increase of arterial hypertension, of which the contribution of radiation exposure is doubtful.

Particularly in the group of patients with ARS Grade II–III, the working ability decreased. However, the so-called Karnofsky performance score made in 1993 for a subpopulation of 89 patients did not reveal differences between the so-called non-confirmed ARS cases and the patients with ARS Grade III, both groups performing poorly (Fig. 4) at a score of 60%. The patients with ARS Grade I and II appeared to have recovered well, with a score of nearly 80%. There were quite a few cases of radiation cataracts developing. No case of cancer was recorded. Among patients with unconfirmed ARS, there was one case of lethal sarcoma of the thigh; in view of the probably low dose received by this person and the relatively short time after exposure, it is not likely that this tumour is radiation induced.

Late skin sequels: the subgroup of patients treated in Munich

Fifteen of the most severely affected patients, the associated diseases of whom could also be representative for all ARS patients, have been treated for skin injuries in Munich, Germany. All patients had been exposed either as working personnel (engineers, physicists, watchmen or constructors) within the reactor during the accident or as members of the cleanup forces in the first days after the accident. All patients have a history of acute radiation disease including prodromi (nausea, vomiting, diarrhoea) with latencies between 30 minutes and 48 hours post exposure. Two patients had received a bone marrow graft. Symptoms of mucosal and/or cutaneous involvement developed within 4 to 26 days post exposure. The cutaneous symptoms of some of the patients have also been described [27, 31].

In ten of the patients, radiation ulcers, keratoses and severe cutaneous and subcutaneous fibrosis developed in the years following exposure with varying courses,

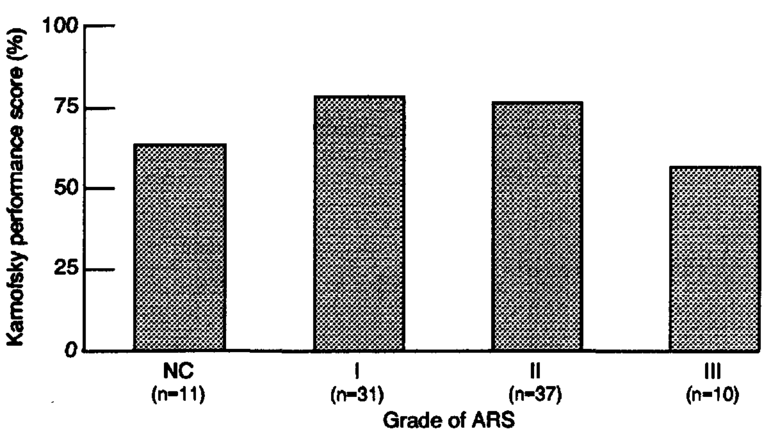

FIG. 4. Karnofsky clinical performance score of a subgroup of 89 patients, related to the initial grade of ARS. NC: diagnosis of ARS not confirmed. (Source: Dr. M. Weiss.)

generally showing signs of progression. In three cases, amputation was necessary (left lower thigh, fifth right finger, fifth left toe).

All patients have been followed up with a six months period for therapeutic efficacy of the applied treatment modalities, so far for more than 4 years. The most frequently observed cutaneous signs were dryness of the affected skin with craquelé-like appearance, spray-like telangiectasias, epidermal atrophy, radiation keratoses and ulcers. This was accompanied by partly severe dermal and subcutaneous fibrosis, determined both by biopsy and cutaneous sonography. Additionally, haemangiomas, haematolymphangiomas and a lentiginous hyperpigmentation were characteristic findings. Involvement of skin appendages included circumscribed alopecia not only in the scalp area, but also on trunk and perimamillar area, and nail changes with longitudinal streaks and splinter bleeding near the end of the nail bed. In the close vicinity of affected skin, areas which had been covered by layers of dry clothes were often unaffected, demonstrating the short range of the beta irradiation received. Involvement of hands and feet lead to decreased mechanical resistance of the radiation damaged skin, causing severe incapacitation.

The records of these 15 patients provide a good source for studying the development of associated diseases in ARS patients. The general condition of the patients at the time of the first examination (September 1991 to March 1992), i.e. five years after the accident, was good. The skin of some of the patients appeared prematurely aged. Apart from cutaneous lesions, a variety of additional radiation associated symptoms were noted: initial cataract formation, hyperesthesia in affected areas, recurrent viral and bacterial infections. Serological examination revealed positive serology for hepatitis B and C in the majority. Besides a small prolactinoma in one patient, no signs of neoplastic growth (tumours) were detected. The associated diseases and symptoms as of February 1996 are given in Table VI. The patient with a myelodysplastic syndrome is the one who has died recently. Perhaps not surprisingly, characteristic radiation effects such as cataracts and impaired fertility are as frequent as headaches and clinical signs of 'depressions', hepatitis B/C and caries, which are not necessarily radiation related, although it is not excluded that radiation exposure influenced or aggravated their development and course.

4. FUTURE PROSPECTS

The prospects for the patients

The associated diseases in the 15 patients treated in Munich are perhaps at the time a good account of the ailments of the Chernobyl patients who received high doses. Although these patients are among the most severely affected by radiation,

TABLE VI. ASSOCIATED SYMPTOMS AND DISEASES IN THE 15 MOST SEVERE CASES OF SKIN INJURY DUE TO THE CHERNOBYL ACCIDENT (of the group of patients examined and treated in Munich)

Signs and symptoms	Number of patients/total
Paradentoses, caries	12/15
Cataract	10/15
Headaches, 'depression'	10/15
Impaired fertility	10/15
Hepatitis B/C	8/15
Thyroid dysfunction	4/15
Hypertension	2/15
Asthma	1/15
Yersinia arthritis	1/15
Diabetes	1/15
Clinical (pre)neoplastic changes	
— precancerous skin lesions (keratoses)	9/15
— prolactinoma	1/15
— myelodysplastic symdrome	1/15

evidence exists that their companions with similar or lower exposures have a similar variety of diseases. It will be necessary in the near future to distinguish radiation induced lesions and sequels from health problems intrinsic to the population.

If we take the grade of ARS as a dosimetric parameter, there are presently some 90 patients alive that have received appreciable to high doses of radiation. Apart from the fact that these patients have an increased risk of tumour development, they are also prone to radiation effects which have not been studied in detail for the dose received, such as cardiovascular diseases, digestive problems, increased susceptibility to infections, cataracts and, in quite a few, further deteriorating skin lesions. In addition, there is experimental evidence to indicate that kidney and liver functions may decline, while the reactions to chronic somatic as well as psychological stress may further aggravate the health of these patients.

The scientific analysis of the health status of these patients has hardly begun and, both in terms of the interests of the scientific community and of the well-being of these patients, medical care should be provided at a high level for many years to follow. This should preferably be co-ordinated by a single highly qualified centre that co-ordinates both the clinical monitoring and treatment and the processing of the data.

Future accident management

The Chernobyl cases have taught us that much needs to be improved in the clinical management of ARS in accident situations, in general complicated by radiation injury to the skin and injuries that are not radiation related. It is conceivable that, in any future accident, bone marrow transplantation as applied in the most severe cases of the Chernobyl accident will not be used. New agents have become available, in particular a group of cytokines collectively known as the haemopoietic growth factors, which have the capacity to stimulate the recovery of the blood and immune system.

Although much research is still needed for the pharmaceutical development of these agents and in particular the most optimal combination of growth factors has not yet been established, future accident victims will almost certainly be treated with thrombopoietin [33] to stimulate platelet production as well as with one of the stimulators of the production of neutrophilic granulocytes. However, experimental studies have already shown that the haemopoietic growth factors are not effective following radiation doses higher than 7 Gy for X rays, which means that these agents will not be effective for the most severe cases of ARS in patients not dying from gastrointestinal damage ($>$ 10 Gy) or from other injury. New advances in stem cell biology and procurement of haemopoietic stem cells from peripheral blood [34] or umbilical cord blood [35, 36] make it likely that those high dose victims can be successfully treated with donor stem cell concentrates.

The immediate diagnosis of the extent of the radiation damage is of the greatest importance for a successful treatment strategy. New molecular parameters may assist in a more accurate assessment of the extent of gastrointestinal damage than on the basis of anorexia, vomiting and diarrhoea alone. Both understanding of the molecular events accompanying the acute inflammation reaction following radiation exposure of the skin and new imaging techniques make it likely that radiation damage of the skin can be assessed and quantified at an earlier stage than was possible in 1986. The observation that haemopoietic stem cells start circulating in the peripheral blood immediately after acute radiation exposure provides as such an additional parameter to quantify the extent of depletion of the stem cell pool [37], making it likely that also here the diagnosis can be made more accurately.

In summary, both in terms of diagnosis and treatment the scientific advances are such that future radiation accident victims may be provided with better opportunities for survival and quality of life than has been the case for the Chernobyl patients. The Radiation Emergency Medical Preparedness and Assistance Network (REMPAN) led by WHO has recently included the above recommendations.

5. CONCLUSIONS

The Chernobyl accident resulted in a total number of 237 individuals who were suspected of suffering from acute radiation sickness (ARS). The number of acute casualties (deaths) that were directly attributable to the accident was 30 (one further death was thought to have been due to a coronary thrombosis).

The diagnosis of ARS was confirmed in 134 cases of the 237 people hospitalized. Of these 134 patients, 41 had mild (Grade I) ARS and the case of one additional patient is still disputed; all survived. Fifty patients, of whom one died, had Grade II ARS. Seven patients died out of 22 with Grade III ARS. All except for one of the most severely affected 21 patients who suffered from Grade IV ARS died. Among the latter, the gastrointestinal damage was a most severe problem in 11 patients who received doses higher than 10 Gy and resulted in early and lethal changes in intestinal function. The death of 26 of the 28 patients who died in the first 3 months after exposure was associated with skin lesions involving over 50% of the total body surface area.

After this acute phase, 14 additional patients have died over the last ten years. Their deaths do not correlate with the original severity of ARS (Fig. 2) and may therefore not be directly attributable to the radiation exposure. The careful follow-up of long term health effects is the subject of Background Paper 3.

There is little doubt that the ARS patients, also those with severe skin injury, have received the best possible treatment in line with the state of knowledge at the time in the most experienced centre available. The therapy of bone marrow transplantation recommended at the time was of little benefit. From today's knowledge this is very well understandable, in view of the intrinsic immunological risks of the procedure, the heterogeneous exposure characteristic for the accident situation and the complicating other injury, such as unmanageable intestinal radiation damage or skin lesions. The bone marrow damage can in future cases best be managed by rapid administration of haemopoietic growth factors, of which the most optimal combination and dose scheduling, however, still needs to be worked out. Also for other damage, new diagnostic tools have become available which may contribute to a more accurate prognosis and more tailored treatment.

There is good evidence that the quality of life of the surviving patients may be amenable to improvement. At least the more severely affected patients suffer presently from multiple ailments and are in need of up to date treatment and secondary prevention; also their mental health might be suboptimal. More has to be done in the future to distinguish among the disease patterns encountered between those attributable to the radiation exposure and those due to confounding factors intrinsic to the population. The follow-up of these patients needs to be assured for the forthcoming two to three decades.

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DISCUSSION ON BACKGROUND PAPER 1

S. NAGATAKI (Japan): Far more people have died or suffered from acute radiation effects as a result of the atomic bomb attacks on Hiroshima and Nagasaki than as a result of the Chernobyl accident. Would it not be useful to carry out a comparative study of the two groups of victims?

I. SHIGEMATSU (Japan): The atomic bomb attacks resulted not only in radiation exposure but also in effects due to — for example — the heat and the blasts, so that the estimated LD 50 value of 2.8 Gy is probably an underestimate.

Moreover, there are other factors — such as the non-availability of proper medical treatment in wartime Japan — which make the Hiroshima/Nagasaki experience incomparable with the Chernobyl experience as regards acute radiation effects.

When comparing the two groups of victims, the differences in exposure type and radiation dose should also be taken into account.

L.A. ILYIN (Russian Federation): I should also like to respond to Dr. Nagataki's question.

Among the major differences between the Hiroshima/Nagasaki experience and the Chernobyl experience were: firstly, the fact that high gamma and neutron radiation dose rates occurred in Hiroshima and Nagasaki, whereas there was no neutron radiation in the case of Chernobyl; secondly, the gamma radiation dose rates fell more uniformly in Hiroshima and Nagasaki; thirdly, the damage to skin was caused mainly by a combination of gamma and beta radiation in the case of Chernobyl and by gamma radiation alone in Hiroshima and Nagasaki; and fourthly, there was very little incorporation of short-lived iodine nuclides, rare-earth elements, etc., in Hiroshima and Nagasaki.

As regards medical treatment, to which Prof. Shigematsu just referred, I would note that by the time of the Chernobyl accident we had in the former Soviet Union already dealt with some 450 cases of acute radiation sickness.

I agree with Prof. Shigematsu that the LD 50 value of 2.8 Gy in the case of the Hiroshima and Nagasaki victims is probably an underestimate. In the case of the Chernobyl victims, we put the LD 50 value at about 3 Gy, although that figure is based — fortunately — on only 28 fatalities.

F.A. METTLER (United States of America, Chairperson): I should like to ask Dr. Wagemaker what he thinks the LD 50 value would be today with medical treatment.

G. WAGEMAKER (European Commission, Rapporteur): Before responding to Dr. Mettler, I should like to draw attention to a sentence in Section 3.1 of the

Background Paper which underlines the point made by Prof. Ilyin — "The Chernobyl accident led to exposure with high amounts of beta irradiation ..., causing a clinical pattern of involvement which was different from the experience of Hiroshima and Nagasaki ...".

As regards the LD 50 question, I do not think the Chernobyl data are very suitable for deriving an LD 50 value — not so much because of the small number of fatalities as because of the fact that the persons in question received intensive treatment based on the state of the art at the time which shifted the LD 50 value to something like 8 Gy.

In the case of experimental animals, even without bone marrow transplantations — but with full support — the LD 50 value becomes similar to the LD 50 value for the gastrointestinal syndrome, shifting to about 10 Gy of X rays.

R.J. BERRY (United Kingdom): Dr. Wagemaker, the Rapporteur, dismissed dental caries in the patients who had severe skin reactions as probably not related to radiation. However, if those patients who had severe skin reactions also had severe stomatitis, this may have led to dental caries, as is commonly seen in radiotherapy patients where the oropharynx has been treated.

G. WAGEMAKER (European Commission, Rapporteur): Because of the exposure, most of the patients had mucositis, and I would agree that caries is a late effect. However, the incidence of caries in different age groups of patients did not differ much from that in the same age groups for the general population.

F.A. METTLER (United States of America, Chairperson): We found much the same thing in the International Chernobyl Project. The incidence of caries in children was amazing.

C. ZUUR (Netherlands): With regard to the incidence of caries, before a bone marrow transplant is performed, all the "rotten elements" in the patient's mouth are removed, as they are a major source of infection. I understand that this procedure was followed in the case of Chernobyl accident victims.

R.J. BERRY (United Kingdom): Did acute radiation syndrome occur only in workers at the Chernobyl NPP and emergency personnel or also in the general population?

L.A. ILYIN (Russian Federation): According to our data (the accuracy of which I cannot vouch for), there was only one case of acute radiation syndrome in the general population — a woman who worked in her kitchen garden the evening after the Chernobyl accident and suffered from radiation burns on both shins.

I should like to make a comment in connection with this question. The number of persons brought to the various clinics initially and hospitalized was 237 — all of them Chernobyl NPP workers and emergency personnel. As stated in the Background Papers, acute radiation syndrome was confirmed in 134 of these 237 cases.

However, many members of the general population, concerned about their state of health, were subsequently hospitalized for examination purposes and, although they were essentially healthy, were diagnosed as suffering from "vegeto-vascular dystonia", which is one of the late complexes of syndromes following acute radiation sickness. The reason for this diagnosis was that clinics had been instructed by the authorities to enter it into the medical records of the people in question in order that these might have their periods of hospitalization paid for by their trade union health care funds. Unfortunately, many of these people believed as a result that they had had acute radiation sickness.

R.J. BERRY (United Kingdom): With regard to the individuals who were not confirmed as having acute radiation syndrome but who had low Karnofsky performance scores, were they just worriers who felt ill irrespective of any radiation exposure?

D.C. GARNER (United States of America): Fatigue appears to be universally observed regardless of how much or which part of the body had been treated. This points to a humoral factor or cytokine released into the body from normal tissue that has been damaged, but the exact mechanism has not been identified.

I should like to use this opportunity in order to ask a question: is there any reason to think that parenteral nutrition (through a catheter) is preferable or inferior to enteral nutrition (through a feeding tube) in the case of very sick individuals?

A. BARABANOVA (Russian Federation): All patients who have received a dose of 5–6 Gy or more should be fed intravenously.

J.S. NATHWANI (Canada): With regard to the 237 persons exposed to high levels of radiation dose, how was the dose estimated for each person?

F.A. METTLER (United States of America, Chairperson): Doses were estimated using cytogenetic methods, methods based on the observation of symptoms (nausea, vomiting, etc.) and methods based on the haematological response. In this connection, I would mention that in a number of cases the different methods yielded different dose estimates and that a particular method yielded a higher estimate than another one in some cases and a lower estimate in others. However, the various estimates were within about 1 Gy of each other.

This issue is dealt with in one of the annexes to the 1988 UNSCEAR report. Perhaps Prof. Ilyin would also like to respond.

L.A. ILYIN (Russian Federation): In the case of the patients brought to our clinic on 27 April 1986, we estimated the doses first on the basis of the clinical symptoms and of peripheral blood analyses and then on the basis of chromosome aberrations. In parallel with that, where it was possible we also employed the ESR (electron spin resonance) method, using pieces of clothing and sometimes — especially when the patients had died in the meantime — teeth.

Where the doses were high, the estimates obtained with physical dosimetry, clinical dosimetry and biological dosimetry methods agreed fairly well.

There is a problem, however, which has still not been resolved. When the doses associated with instantaneous, acute gamma or gamma-plus-neutron radiation are estimated using the ESR method or the chromosome aberration test, the results are reliable. On the other hand, when it is a question of protracted exposure, especially with a declining dose rate and — even more so — against a background due to radionuclide incorporation, the calibration curves are in my opinion not adequate.

In the case of radiation burns, we had no doubts about the dose limit estimates, which we obtained using models.

F.A. METTLER (United States of America, Chairperson): In publications relating to most of these patients, doses of 5.6 Gy are mentioned. Do you, Prof. Ilyin, think that it is 5.6 Gy plus or minus, say, 1 Gy or 0.5 Gy for whole-body exposures?

L.A. ILYIN (Russian Federation): With absorbed doses of around 1 Gy, the methods used by us are accurate to within about ±20%; with absorbed doses of less than 0.5 Gy, however, their accuracy — especially in the case of biological dosimetry methods — is poorer (±30–40%).

We in the Russian Federation do not have detailed information on the persons in question for the seven or eight years following the accident. We should like to have such information in order to find out whether the curve for the elimination of damaged chromosomes changed over the years. On the basis of that curve we could retrospectively estimate the original doses.

M. FERNEX (Switzerland): I should like to make a comment regarding diabetes mellitus.

In November 1995, at the WHO International Conference on the Health Consequences of the Chernobyl and other Radiological Accidents, the Ukrainian Minister of Health mentioned a 25% increase in the incidence of this disease, and recently there was also mention of an increase in Belarus — by more than 100% among children in the Gomel region. Accordingly, I think diabetes mellitus should be monitored as carefully as thyroid cancer.

A. PINCHERA (Italy): There are two types of diabetes mellitus, the insulin-dependent type (IDDM) and the non-insulin-dependent type (NIDDM), and it would be interesting to know which type was involved in the increases just referred to, since IDDM is regarded as an autoimmune disorder, stress being considered a possible triggering factor in genetically predisposed individuals.

M. FERNEX (Switzerland): The type involved was IDDM, which is not considered to be radiation-related. However, I still think it should be carefully monitored.

C. ZUUR (Netherlands): I should like to make a few comments regarding Table VI of the Background Paper.

The table points to ten headache or depression sufferers among the 15 skin injury patients in question. I am surprised that not all 15 patients suffered from depression.

The table also points to four cases of thyroid dysfunction. However, it must be remembered that thyroid dysfunction is endemic in the regions most affected by the Chernobyl accident.

As to keratoses and myelodysplastic syndrome, they are common within the age group in question, so I do not think one should say that they are probably radiation-related in the cases referred to here — only that there is a higher probability that they are.

F.A. METTLER (United States of America, Chairperson): I think that in tables like Table VI one should in future be more specific. For example, "thyroid dysfunction" is a broad concept, covering conditions ranging from hypothyroidism to goitre.

A.R. OLIVEIRA (Brazil): Were haemopoietic growth factors used in the treatment of Chernobyl patients?

A. BARABANOVA (Russian Federation): They were used in two cases, at very late treatment stages, without any pronounced effect. It was not a success.

G. WAGEMAKER (European Commission, Rapporteur): At the time of the Chernobyl accident, the only haemopoietic growth factors available were GMCSF and GCSF, and they were still only at the experimental stage. Now we have growth factors — such as thrombopoietin — which can be very effective. However, growth factors are not a miracle drug; with whole-body radiation doses of 7 Gy (X ray equivalent) or more, most growth factors are ineffective owing to a lack of bone marrow stem cells. Then one must resort to the modern equivalent of bone marrow transplantation — stem cell transplantation — in order to shorten the period of pancytopoenia.

A.R. OLIVEIRA (Brazil): What were the indicators of spontaneous bone marrow recovery in the Chernobyl patients?

F.A. METTLER (United States of America, Chairperson): The indicators were normal levels of platelets and of red and white blood cells.

In that connection, I would mention that in most cases where I have treated patients with metastatic diseases using radioactive strontium the levels of platelets and of red and white blood cells have returned to normal after being reduced through the treatment. The recovery time has been longer after the second radioactive strontium administration than after the first, however, and longer still after the third, at which point it is difficult to know how many bone marrow cells are left and how much stimulation they are receiving.

I. TURAI (International Atomic Energy Agency): I should like to draw attention to the discrepancies in the data presented here on the lethal radiation consequences of the Chernobyl accident. Presenting the WHO Updating Report at yesterday's Briefing Seminar, Prof. Tsyb said that 28 persons died of acute radiation syndrome (ARS) and that nine died of radiation sickness in the ten years following the Chernobyl accident; presenting the EC Updating Report, Dr. Sinnaeve spoke of 29 deaths due to ARS followed by 14 due to radiation sickness by the end of 1995; now Dr. Wagemaker has spoken of 28 deaths due to ARS and stated that of the 14 deaths occurring between 1986 and 1995 in the group of professionals who received acute radiation exposures at Chernobyl, only two could be attributed to radiation — these were cases of myelodysplastic syndrome with confirmed ARS of grade III. From the medical point of view I find Dr. Wagemaker's conclusion realistic (it is in good agreement with data recently published by Prof. Ilyin) and I would propose that it be cited in future publications regarding lethal radiation consequences among professionals during the period 1986-1995.

L.A. ILYIN (Russian Federation): Dr. Turai has raised a key issue. The figures have varied from meeting to meeting, and we in the Conference's Advisory Committee have been trying to reconcile them.

I do not think that this issue will be resolved here, but I am grateful to Dr. Turai for raising it.

G. SOUCHKEVITCH (World Health Organization): Perhaps I can help to clarify the situation regarding the number of deaths during the period 1986–1995 among the individuals hospitalized with acute radiation sickness in the early days after the accident.

All 14 deaths are included in Table V of the Background Paper presented by Dr. Wagemaker; they consist of nine cases of confirmed acute radiation sickness and five cases of non-confirmed acute radiation sickness. In the WHO Updating Report, Dr. Tsyb provided data only on the nine cases of confirmed acute radiation sickness.

A.Yu. BONDAR (Ukraine): The groups of professionals who received doses of more than 50 cGy, determined individuals who have remained or settled in the contaminated zone, evacuated children and employees of the Chernobyl NPP have proved to be fairly heterogeneous as regards the cytogenetic effect found in the peripheral blood lymphocytes. This reflects various intensities of absorbed radiation dose and also possible individual variability of cytogenetic response under the influence of the radiation factor.

On the basis of the data obtained, we can assume that the variability of cell sensitivity in experimental groups to the effects of the mutagen (additional radiation exposure) was caused not only by hereditary factors, but also by previous irradiation.

A fairly substantial increase in various ''doublestrike'' aberration rates regarded as markers of radiation influence was found in the group of individuals who had received doses of more than 50 cGy and in other experimental groups. This cytogenetic effect reflects the breach of these individuals' genome.

Another peculiarity currently being analysed was an increase in chromosome aberration rate induced by radiation in the cells of the individuals studied. As is well known, the number of stable chromosome aberrations (reciprocal translocations and inversions) is the only reliable cytogenetic criterion of absorbed radiation dose. These chromosome changes do not lead to the mitotic destruction of cells, are not eliminated for a long time and accumulate under the protracted action of radiation. At the same time, the information about the spontaneous level revealed by routine chromosome staining is fairly contradictory. According to data from a cytogenetic investigation of persons belonging to a control group in Hiroshima (exposure dose <0.01 Gy), the number of translocations was 5.60–7.90 per 1000 cells. Similar data have been obtained by American investigators using the fluorescent in situ hybridization test in a study on five unirradiated citizens of Hiroshima. According to the data of the American investigators, the reciprocal translocation rate (5–10 per 1000 cells) is 5–10 times higher than the dicentric and centric ring frequency. Lucas, Poggensee and Straume attribute this phenomenon to the stability of translocations and their accumulation under the influence of clastogenes.

The results of selective cytogenetic investigations of persons who have received doses of more than 50 cGy indicate a statistically significant increase in specific markers of radiation influence after the Chernobyl accident. At the same time, our data reflect the fact that a wide variation in individual sensitivity was found in studies of the chronic influence of low doses of ionizing radiation.

There are data indicating intensification of the DNA repair process in blood lymphocytes of professionals who worked for a long time under conditions of increased radiation background and, as a result, had a lower rate of chromatid exchange.

Essential inter-individual fluctuations in the number of unstable and stable aberrations testify to the existence of individual radiosensitivity and of individual peculiarities as regards the elimination of aberrant cells.

In the light of our analysis, we recommended that the examined individuals be regarded as a group subject to abnormally high risk which needs careful and permanent clinical observation.

We are continuing to study the prognostic value of the revealed cytogenetic changes and their correlation with internal and external irradiation doses.

TOPICAL SESSION 2

Thyroid Effects

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EFFECTS ON THE THYROID IN POPULATIONS EXPOSED TO RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT

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Abstract

EFFECTS ON THE THYROID IN POPULATIONS EXPOSED TO RADIATION AS A RESULT OF THE CHERNOBYL ACCIDENT.

Four years after the Chernobyl accident on 26 April 1986, an increased incidence of thyroid carcinoma (cancer) was noticed in children in Belarus and Ukraine. The increase has continued, with well over 500 cases reported from the areas around Chernobyl. Background Paper 2 considers the size of the increase, with account taken of ascertainment of the evidence that the increase is related to radiation exposure due to the Chernobyl accident, of the isotope or isotopes responsible, and of the likely future effects. External radiation is known to cause thyroid cancer, but radioactive iodine has been used for many years in the treatment of thyrotoxicosis without any increase in thyroid carcinoma. The majority of cases of thyroid

carcinoma following exposure to X rays were papillary in type, the latent period was about 5–10 years, sensitivity decreased with increasing age at exposure, and the increase in the risk of induction of thyroid cancer persisted for decades. Over 400 cases of thyroid cancer have occurred in children under the age of 15 in Belarus between 1990 and 1995 inclusive. The increase is greatest in the Gomel oblast, which had relatively high deposition densities. The rate in Gomel is about 200 times that seen in England and Wales, for example, for this normally rare tumour in children. About 150 cases have occurred in the 'contaminated' northern oblasts of Ukraine: an incidence about 20 times higher than in England and Wales, and 7 times higher than in southern Ukraine. The diagnoses of thyroid cancer have been confirmed in over 90% of the cases available for study (over half of all cases are available); increased ascertainment of cases from screening has been excluded as a major contributory factor. Virtually all cases were papillary in type. The situation in the Russian Federation is less clear. In the oblasts most affected by radiation, there appears to have been an increase in childhood thyroid carcinoma, but probably to a lesser extent than in Belarus or in Ukraine. There is strong evidence that the increased incidence of childhood thyroid cancer is due to radiation exposure as a result of the Chernobyl accident, based on the geographical and temporal distribution of the cases. In both Belarus and Ukraine they are commonest in the oblasts close to Chernobyl that had high levels of contamination. The incidence in children born more than 6 months after the accident drops dramatically to the low levels expected in unexposed populations. The evidence that the increase is due to radioactive isotopes of iodine is at present circumstantial. It is based on the fact that the increase in cancer in the exposed population is limited to thyroid tumours. The relatively high thyroid doses are due to the thyroid's ability to concentrate radioiodine, which was deposited at high levels in areas close to the Chernobyl plant. Other contributory factors cannot be excluded, but appear unlikely to have played a major role. The likelihood of developing thyroid carcinoma is much greater in those who were very young at exposure, and drops rapidly with age. This is consistent with the known high uptake of radioiodine in young children and the higher sensitivity of young children to the carcinogenic effect of X radiation on the thyroid. ^{131}I was the major cause of radiation exposure of the thyroid. Short lived isotopes of iodine could have played a role in the immediate vicinity of the plant. A reported increase in incidence of hypothyroidism and of thyroid nodules in Gomel oblast is also consistent with radioiodine exposure. Future effects are difficult to predict, because of a lack of experience of exposure at this level of a large population. The cohort made up of those who were very young at the time of the accident and were exposed at high levels is likely to carry an increased risk of developing thyroid cancer for many years. The level of risk could be high; further studies are needed to establish a dose-response relationship and to improve the prediction of likely future incidence. Thyroid cancer, if properly treated, does not carry a high mortality and the observations suggest that targeted screening of those exposed at high levels at a young age may be effective.

1. BACKGROUND AND ISSUES

The Chernobyl accident released very large quantities of radioactive isotopes into the air, including large amounts of radioactive iodine. The population in the area around Chernobyl, particularly in southern Belarus and northern Ukraine, was exposed to radiation at relatively high levels. The thyroid gland, since it concentrates iodine to make thyroid hormone, was exposed to higher levels of radiation than the other tissues of the body.

The radioactive isotope of iodine, iodine-131, was the main isotope of iodine deposited. It has been extensively used in the treatment of thyrotoxicosis and careful epidemiological studies have not shown any increase in thyroid cancer in treated patients [1]. However, when the thyroid gland has been exposed to X rays through the treatment of some other condition in the neck, thyroid cancer has occurred in a small proportion of those treated, usually 10 or more years after exposure [2]. Nearly all the studies describing this link between exposure to X rays and the later development of thyroid cancer have been for patients exposed as children.

In view of the absence of any increase in thyroid carcinoma in patients treated with radioactive iodine, the reported numbers of thyroid cancers in children in areas where radiation exposures as a result of the Chernobyl accident were relatively high [3, 4] were therefore surprising, as was the very short time (four years) between exposure and the beginning of the increase. Thyroid cancers in animals can be induced by exposure to external radiation, by exposure to radiation from iodine-131 or by chemical carcinogens. The incidence of thyroid cancer in man is also related to the amount of non-radioactive iodine in the diet. One particular very small type of thyroid cancer is remarkably common in the adult population; it is very slow growing, not life threatening and not usually detected in life, raising the possibility that screening children for thyroid disease has detected tumours that would not otherwise have been found. In the four years since the first report in the western literature of the increase, a number of studies have been carried out to investigate the relationship between the reported increase in thyroid cancers and exposure due to the Chernobyl accident.

The main aim of this Background Paper is to document the evidence available on (a) the number and type of thyroid carcinomas occurring in children in the areas of the three countries most affected by the Chernobyl accident; (b) the radiation exposure of the thyroid for the population; (c) the correlation of thyroid cancer incidence with exposure; (d) the effect of ascertainment on the incidence of thyroid cancer; (e) the relationship to age of the development of thyroid cancer; (f) the possible role of factors not related to Chernobyl; and (g) thyroid effects other than cancer. Because of the very large amount of information available, the Background Paper will concentrate on evidence from collaborative international studies. The discussion will consider the interaction of the different topics reviewed and deal particularly with the main issues: the size of the increase in incidence in thyroid carcinoma with ascertainment taken into account, the evidence that the increase is related to exposure due to the Chernobyl accident, the isotope or isotopes responsible, and the likely future effects.

2. BACKGROUND SCIENTIFIC KNOWLEDGE

2.1. Radiation exposure of the thyroid for the population

The Chernobyl accident on 26 April 1986 is the only instance of the radiation exposure of a large population at relatively high levels as a consequence of a nuclear accident. Large amounts of radioactive material were released, and one of the main constituents was a radioactive isotope of iodine, ^{131}I. Present estimates suggest that ^{131}I with an activity of $\sim 1.8 \times 10^{18}$ Bq was released [5], up to three times more than originally estimated [6]. This is discussed further in Background Paper 5.

In addition, large quantities of radioactive tellurium were released, as the isotope ^{132}Te, which decays in a few days to a very short lived isotope of iodine, ^{132}I. The activity of the ^{132}Te released is presently estimated as $\sim 1.2 \times 10^{18}$ Bq [5], a few times more than suggested by the original estimates [6]. Iodine, including radioactive isotopes of iodine, is absorbed by the human body from food or inhaled as vapour in the air, and is then concentrated very efficiently in the thyroid, where the iodine is an essential constituent of the two main hormones produced by the gland. Exposure to radioiodine therefore leads to irradiation of the thyroid gland, with the possibility that later effects of the exposure could include thyroid tumours or diminished thyroid function due to direct tissue damage.

The deposition of radioactive materials from the Chernobyl accident was complex. It was affected by wind and rainfall over the period of intense radioactive releases, which lasted about a week. Because of its relatively short half-life, exposure of the population to radioiodine and particularly to the short lived isotopes decreased more rapidly with distance from the plant than did exposure to radioactive isotopes of caesium, another important constituent of the releases.

The radioactive iodine enters the blood stream through inhalation or ingestion. Inhalation is likely to have been particularly important near the Chernobyl plant. Ingestion of radioiodine is largely dependent on the iodine content in milk and in vegetables. Iodine in milk is particularly important because deposited radioactive materials on grass eaten by cows is absorbed and concentrated in the cows' milk by the iodide trapping mechanism in mammary epithelium. Any iodine taken in by a pregnant or nursing woman will enter the bloodstream and will also be available for concentration by breast epithelium, or for transfer across the placenta. The foetal thyroid concentrates radioiodine from the foetal circulation after about 12 to 14 weeks of gestation, so that if the mother is exposed to radioiodine after this time there may be consequences for the thyroid of the baby.

Relatively few direct measurements of population exposure were made until a few days after the accident, so that direct data on the uptake of the very short lived isotopes of iodine is not available, and measurements for ^{131}I were made after the time of peak uptake in the cases where it was measured at all. More accurate measurements could be made of two of the other major isotopes released, ^{137}Cs and ^{90}Sr, because of their longer half-lives. The differing ratios of these isotopes in differing areas shows the problem in extrapolating from the distribution of one isotope to another, let alone from longer lived to shorter lived isotopes. This difficulty is compounded by the variation in the ratio of emissions of ^{131}I and ^{137}Cs during the course of the accident.

In addition to radiation exposure of the population through intake of radioactive isotopes, there was a contribution from external radiation, both from radionuclides in the plume carrying the emitted isotopes and from gamma radiation due to ground deposition. The initial estimates of the thyroid dose from ^{131}I in a small group of selected settlements were predicted on the basis of the ^{137}Cs measurements and the ratio of ^{131}I to ^{137}Cs in the release, and some direct measurements. Indicative absorbed doses to the thyroid from ^{131}I in different settlements, which are not necessarily representative of the whole district, ranged from 790 to 2400 mGy for infants and 190 to 370 mGy for adults [7]. Exposure to short lived isotopes of iodine increases this figure, perhaps by up to half [8]; and recent reconsideration of the amount of ^{131}I released, and of the ratio of ^{131}I to ^{137}Cs, suggests that these early estimates may need recalculation.

Studies quoted in Background Paper 3 suggest that the average dose in the whole of Gomel for children aged 0–7 years was about 420 mGy, while doses quoted in the recent appraisal by the Nuclear Energy Agency of the OECD show that the average dose of the children aged 0–7 years assessed in Gomel oblast was about 1 Gy, with over 9% having doses in the range of 10–40 Gy [5].

The results of individual thyroid measurements that were carried out in Ukraine after the accident have been analysed. On the basis of a combination of these results and extrapolation using ^{137}Cs data, for one settlement in Ukraine with a high mean thyroid dose, close to Chernobyl, the mean dose was 3300 mGy for infants and 500 mGy for adults. In Kiev city, considerably further from Chernobyl, the mean thyroid dose for infants was 104 mGy and for adults 41 mGy [9]. The figures quoted are the population means, and there is considerable individual variation. Here too the calculated doses may need upward revision. The thyroid dose for 0–7 year old children in the Bragin region of the USSR was reported as 2100 mGy for the evacuated villages and 1500 mGy for the non-evacuated villages, with doses ranging from 0 to 4000 mGy [7].

2.2. Thyroid cancer, numbers and diagnosis

The treatment of childhood thyroid cancer in Belarus, a country with just over 10 million inhabitants, including 2.3 million children, is centralized at the thyroid unit in the capital city of Minsk. The numbers of thyroid cancers reported in children from Belarus under the age of 15 years at operation in the period between 1986 and 1994 inclusive are shown in Table I and Fig. 1. It can be seen that in the first four years after the accident the numbers were in single figures; while in 1990, 29 cases

TABLE I. INCIDENCE OF THYROID CANCER IN CHILDREN[a] SINCE THE CHERNOBYL ACCIDENT: FOR BELARUS BY REGION

Region	Year										Total
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	
Brest	0	0	1	1	7	5	17	24	21	21	97
Vitebsk	0	0	0	0	1	3	2	0	1	0	7
Gomel	1	2	1	3	14	43	34	36	44	48	226
Grodno	1	1	1	2	0	2	4	3	5	5	24
Minsk	0	1	1	1	1	1	4	4	6	1	20
Mogilev	0	0	0	0	2	3	1	7	4	6	23
Minsk city	0	0	1	0	4	2	4	5	1	10	27
Total Belarus	2	4	5	7	29	59	66	79	82	91	424

[a] Age under 15 years at the time of operation.

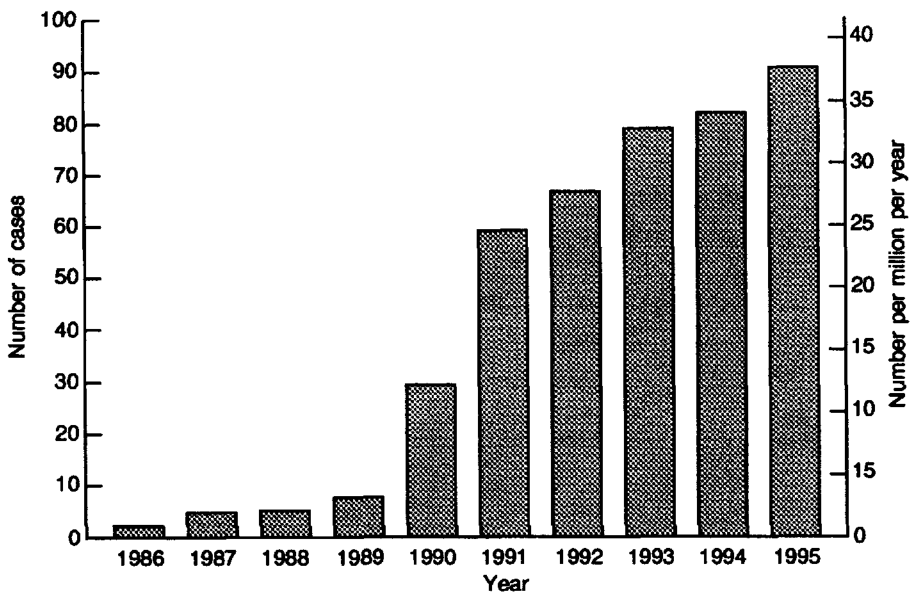

FIG. 1. Annual number of childhood thyroid carcinomas (age under 15 years at the time of operation) in Belarus, 1986–1995.

were diagnosed, rising to 79 in 1993 and 82 in 1994. Among the cases, the female to male ratio overall was 1.7 to 1, the mean age was 10 years, and 5.6% of the children were less than six years of age at the time of the diagnosis. At the time of operation about half of the cases were noted to show direct invasion of surrounding tissues, while two thirds showed lymph node metastases. The latest figures show that 91 cases were diagnosed in 1995. Only four cases have been seen in children born after 1986; however, it must be remembered that these were no more than eight years old in 1994.

In Ukraine, a country of about 60 million people with 10.8 million children under the age of 15 years, the treatment of the great majority of cases of childhood thyroid cancer from the northern part of the country is centralized at the Endocrinology Institute in Kiev, where a register is also maintained of all cases reported from the whole of Ukraine. The annual number of cases of thyroid cancer reported in children from Ukraine under the age of 15 years at operation in the period between 1986 and 1994 inclusive is shown in Table II and Fig. 2. It can be seen that for the first four years, 8 to 11 cases were diagnosed annually, but the figure rose to 26 in 1990 and to 43 in 1993, with 39 in 1994. The female to male ratio was 1.5 to 1, and the mean age was 10.3 years. Of the cases, 60% showed soft tissue invasion at surgery, and lymph node metastases were present in 60% of cases. Only one of the 114 confirmed cases seen at the Kiev Institute was in a child born after 1986.

In the Russian Federation, the oblast of Bryansk was the most affected, although Kaluga and Tula oblasts also had high radiation levels as a result of the accident. The treatment of childhood thyroid cancer is less centralized than in the other two republics. Between 1986 and 1989, only one child with thyroid cancer was recorded, while, between 1990 and 1994 inclusive, 23 cases of thyroid carcinoma were reported in children under the age of 15 at diagnosis [10].

TABLE II. INCIDENCE OF THYROID CANCER IN CHILDREN[a] SINCE THE CHERNOBYL ACCIDENT: FOR UKRAINE, 'CONTAMINATED' AND 'UNCONTAMINATED' REGIONS

Region	Year									Total	Population
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1986–1994	(children)
'Contaminated'[b]	3	0	2	4	12	13	34	28	25	121	2 000 000
'Uncontaminated'	5	7	6	7	14	9	13	15	14	90	8 800 000
Total Ukraine	8	7	8	11	26	22	47	43	39	211	10 800 000

[a] Age under 15 years at the time of operation.

[b] Comprising Kiev city and oblast, and Cherkasse, Zhitomir, Rovno and Chernigov oblasts.

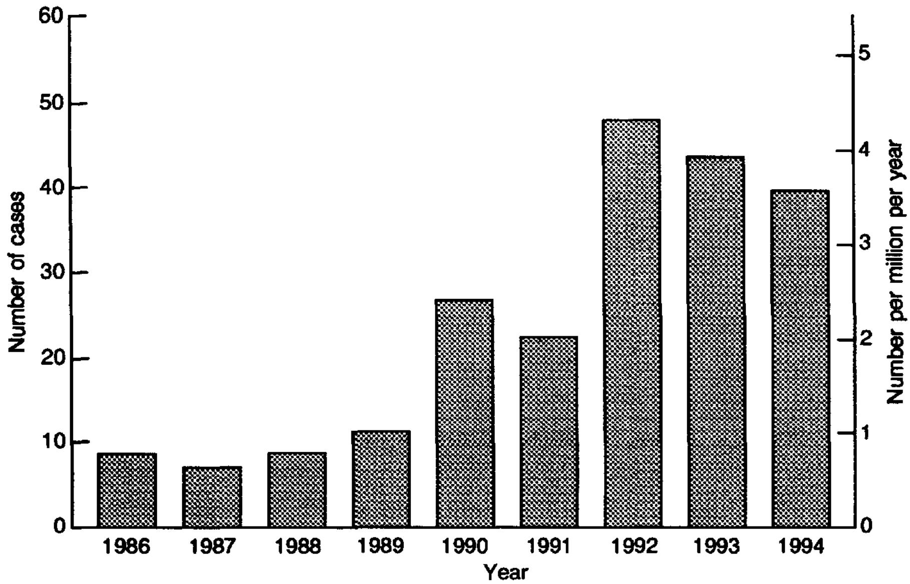

FIG. 2. Annual number of childhood thyroid carcinomas (age under 15 years at the time of operation) in Ukraine, 1986–1994.

There are several different types of thyroid cancer. The main ones found in children are papillary, follicular and medullary carcinomas. They differ in their biological behaviour. The first two are tumours of the thyroid follicular cell; they are relatively well differentiated and the majority are curable. Medullary carcinoma is relatively rare, derived from the thyroid C cell, and not directly concerned with iodine metabolism; about 25% of the cases are familial. While the relative frequency of papillary and follicular carcinoma varies with the dietary iodide intake, papillary carcinoma is usually the most common type.

The histological diagnosis of the thyroid cancers has been investigated by collaboration between groups from the countries of the former Soviet Union and from western countries. A recent survey of cases from Belarus shows that there was 98% agreement in 134 cases studied jointly by staff of the Pathology Institute in Belarus and the Department of Histopathology of the University of Cambridge. The cases studied were equally divided between the earlier cases seen (1990–1992) and later cases (1994–1995); there was no difference in the level of agreement in the two groups. Virtually all the cases (99%) were papillary carcinomas. In the whole series of 298 cases seen in the Institute of Pathology in Belarus between 1990 and 1994, 98% were papillary carcinomas, 1.3% were follicular carcinomas and 0.3% medullary carcinomas.

Study of childhood thyroid cancers in England and Wales has found that the papillary cancers can be subdivided into three main groups: solid/follicular, classic and diffuse sclerosing. There is some overlap between the groups, but the solid/follicular group is relatively more common in younger children in England and Wales, and the classic type is more common in older children. The papillary carcinomas in the children from the exposed areas were also subclassified into solid/follicular, classic and diffuse sclerosing variants, with a few in other groups. Of the cases in Belarus, 72% were solid/follicular in type, 14% classic, 8% diffuse sclerosing and 6% others. All diagnoses in the 134 cases studied in Cambridge were confirmed by immunocytochemistry for thyroglobulin and calcitonin.

The findings in the cases from Ukraine were remarkably similar to those from Belarus. Of the 122 cases of thyroid cancer diagnosed in children under the age of 15 at the Institute of Endocrinology in Kiev between 1990 and 1994 inclusive, 114 have been studied jointly in Kiev and Cambridge, and the diagnoses agreed in over 97%. Of the cancers with agreed diagnosis, 94% were papillary in type, 2% were medullary and 4% follicular carcinomas. The papillary carcinomas could be subdivided into the solid follicular type (76%), classic papillary carcinomas (7%), diffuse sclerosing carcinomas (9%) and other types (7%).

Material from ten cases of childhood thyroid cancer from children from 'contaminated' areas of Bryansk, Kaluga or Tula oblasts of the Russian Federation have been studied by pathologists from the Russian Academy of Medical Sciences in Obninsk and from the University of Cambridge. No tumour was present in the material available for study in one case; the remaining nine cases were all papillary carcinomas, including one papillary microcarcinoma.

In all, these results confirm the diagnosis of thyroid malignancy made in the affected countries, and show that, while the same types of childhood thyroid cancer are seen in the exposed areas as are found in an unexposed population, types other than papillary carcinoma form only a very small proportion of the cases in the exposed areas. Within the papillary carcinomas, the solid follicular subtype is very much more common in the exposed areas than in an unexposed population.

2.3. Thyroid carcinoma, immunocytochemical and molecular biology studies

These studies have been carried out to determine whether there are any specific characteristics of thyroid tumours in children exposed to radiation. Immunocytochemical investigations have been carried out on the great majority of these tumours from all three countries and compared with the findings in childhood thyroid cancers from England and Wales. They included studies of differentiation markers to confirm the cell type in all the carcinomas studied, in most cases used together with in situ hybridization to demonstrate the specific mRNA. No specific changes were seen between the tumours from the different countries with these techniques.

Molecular biological studies of six growth control genes relevant to thyroid cancer were carried out in a collaboration between countries of the former USSR and groups from Cambridge, Brussels, Naples and Munich.

Mutations in one of the three ras oncogenes are commonly involved in a wide variety of human tumours, and have been described in adult thyroid tumours. The three ras genes have been studied by PCR and direct sequencing in formalin fixed material.

The ret oncogene is activated by rearrangement in a proportion of papillary thyroid carcinomas, but has not been found in other types. The rearrangement activates part of the normally inactive ret gene by bringing it next to an active gene; at least three separate rearrangements (ret PTC1, 2 and 3) occur. Expression of the ret gene has been studied using RT-nPCR for a 90 base pair sequence within the tyrosine kinase domain and direct sequencing. The type of ret gene translocation has also been studied. The TSH receptor is a gene capable of stimulating thyroid growth and function. It is activated by point mutation in some thyroid tumours. p53 is an oncogene which is widely involved in human neoplasia and, although it is not usually involved in the early stages of thyroid carcinogenesis, a study has been performed to look for p53 mutations in possible radiation induced tumours.

Overall, the results show a close link between the type of oncogene involved and the pathological type of tumour found, so that the increased frequency of thyroid carcinoma in children in the areas around Chernobyl is an increase in a particular type of thyroid tumour, papillary carcinoma, associated in many cases with rearrangement in a particular oncogene, ret. Three studies of small series of childhood cancers from Belarus have suggested involvement of differing types of ret gene rearrangement [11–13]. A larger series has not shown any specific type of rearrangement [14]. No increase has been shown in activation of the other types of oncogenes known to be associated with thyroid carcinogenesis which were studied: the three ras genes, TSHr and p53 [14].

2.4. Correlation of thyroid cancer incidence with radiation exposure

The correlation of thyroid cancer incidence with radiation exposure can be carried out on an individual or a population basis. The number of measurements of children that were carried out after the accident was not large, so individual correlation must rely largely on reconstructed doses. A detailed population comparison is also difficult owing to a lack of accurate information on the distribution of deposited radioiodine in different areas. Distance from Chernobyl has been used as a rough proxy for radiation exposure in Ukraine [15].

In Belarus, the Gomel oblast, which borders Ukraine close to Chernobyl, had the highest exposure levels. Over 1990–1994, 172 cases occurred in children from Gomel, with a current population of 0.37 million children, compared with 143 cases in the rest of Belarus, with 1.96 million children. The crude rates for childhood thyroid cancer in Gomel over 1990–1994 are therefore 92.0 per million children per year, and for the rest of Belarus 14.6 per million children per year.

Similarly, in Ukraine, the northern oblasts which border Belarus had much higher radiation levels than the remainder of Ukraine. In the six 'contaminated' oblasts, with a population of 2 million children, 112 cases occurred over 1990–1994, and 65 cases in the rest of Ukraine with a population of 8.8 million children. The crude rates for the northern oblasts of Ukraine are 10.6 per million children per year, and for the rest of Ukraine 1.5 per million children per year.

In the Russian Federation, the southwestern part of Bryansk oblast borders the Gomel oblast of Belarus, and areas in this region had high radiation levels, with children having a whole body content of ^{137}Cs that was as high as for children from Gomel. Information on the basis of which crude rates for the 'contaminated' parts of the Russian Federation could be estimated is of uncertain accuracy, but it seems likely that the rates are lower than those for areas with equivalent levels of ^{137}Cs activity in the other two countries.

The rates in Belarus and Ukraine before Chernobyl, and the rate in England and Wales in a 30 year study [16] are all about 0.5 per million children per year. We can therefore conclude that there has been a very large increase in incidence of childhood thyroid carcinoma in the areas around the Chernobyl plant and that this is probably correlated with radiation exposure due to the accident.

2.5. Effect of ascertainment on the frequency of detection of thyroid carcinomas in children

Thyroid carcinoma is normally an extremely uncommon tumour in children, and in adults accounts for about 1% of the cases of clinically significant cancer. However, small papillary carcinomas are relatively common in adults at autopsy, with prevalence figures for autopsy populations quoted between 6% and 35% [7]. The highest figures were obtained when great care was taken in examining the gland by multiple sections, and such glands include many minute lesions. These tumours were originally referred to as 'occult tumours' but were more recently classified as papillary microcarcinomas and were defined as being primary papillary carcinomas under 1 cm in diameter.

The frequency of these tumours in children is not known with certainty because only very small numbers of children's thyroids have been studied at autopsy. Data taken from available reports suggests that they are less common than in adults and that the mean size of the tumours in children is less than that for adults. Six cases were reported in 139 patients under the age of 20 years. The largest in the five cases for which the size was recorded was 0.2 cm and the mean diameter was 0.07 cm [17]. Papillary microcarcinomas are usually of the classical papillary type; some are follicular, but the solid component common in the tumours in the affected countries of the former USSR is not recorded.

Occult follicular carcinoma is extremely rare if it exists at all, but occasional sporadic cases of occult medullary carcinoma have been recorded, and screening can detect familial medullary carcinomas in childhood. Screening would be expected to give a temporary increase in the incidence of the tumour being sought if smaller cancers are detected which would have progressed to clinically apparent ones, and a long term increase if small cancers are detected which do not progress to clinically significant tumours. One well documented study in Chicago observed the results of widespread publicity about the relationship between childhood radiation and thyroid cancer with screening of adults who had been exposed to radiation many years previously. The observed increase in incidence of thyroid cancer at first was seven-fold but later diminished [9], and it was accompanied by a reduction of the mean size of the tumours. It is not clear what proportion of those tumours detected by screening in adults showed direct invasion of extrathyroid tissue, but it seems to have been small.

Screening programmes for thyroid tumours in children, supported by the IPHECA programme [10] of the World Health Organization (WHO), were started in Belarus and Ukraine in the second half of 1992. The increase in thyroid tumours had been noticed in both republics from 1990. The age range screened in Ukraine was from 7 to 18 years; some locally organized screening had been carried out from the time of the accident. Large scale screening has been concentrated in the areas with higher radiation levels. It is estimated that in Belarus, up to the end of 1994, 13 000 children in Gomel oblast and 5000 in Mogilev had been screened. In Ukraine, 12 600 children and adolescents had been screened up to the end of 1994 in five regions of two 'contaminated' oblasts (Kiev and Zhitomir).

In one small study for Belarus, 12 of 50 cases of thyroid carcinoma in children had been detected by targeted screening in children, the remainder had presented through traditional routes, either by a parent or by a routine school examination [18]. The formal screening in the IPHECA supported project made a small contribution to the total numbers of tumours found; in Ukraine, only five cases of thyroid cancer were detected in this programme in the whole period. Screening, including ultrasound examination of the thyroid, was also carried out as part of the Sasakawa study of children in five centres, two in Belarus, two in Ukraine and one in the Russian Federation.

The 1995 report of the Sasakawa study shows that 19 children in the Gomel oblast in Belarus were found to have thyroid cancer, out of 14 000 examined, compared with two out of nearly 18 000 in Mogilev oblast in Belarus; five and six respectively out of nearly 19 000 children in each of Zhitomir oblast and Kiev in Ukraine; and four out of about 17 500 children in Bryansk oblast in the Russian Federation [19]. However, routine school examinations were also carried out. In many centres in Ukraine these included neck palpation. Over half the Ukrainian cases were found in school examinations, while between 35 and 40% of the cases presented through the child being taken to a doctor by the parents. We can conclude that formal screening has not made a significant contribution to the number of cases observed, but enhanced school examinations may have advanced the time at which some tumours were recognized.

2.6. Relationship of development of thyroid carcinomas to age

The age distribution at operation in a study of 154 children with thyroid cancer in England and Wales showed a smooth increase between the ages of six and 14 years [16]. In contrast, the age distribution at operation in both Belarus and Ukraine between 1990 and 1994 showed a peak at 8–9 years, with a subsequent fall in numbers (Fig. 3). Analysis of the cases in Belarus shows that the peak age of the children operated in 1993–1994 was higher than that of children operated in 1990–1991 (Fig. 4). This observation is consistent with a cohort effect, with one age group of children carrying an increased risk of developing thyroid cancer in comparison with the others.

To investigate this further, a preliminary analysis has been carried out of the Belarus cases, dividing them into cohorts based on the age at exposure. Within each cohort, the number of cases in general increased with age at operation, unlike the cases overall, which first increased and then decreased with age. The number of cases by age at operation for each cohort separately was compared with the number expected based on a study of 154 cases of childhood thyroid cancer over a 30 year

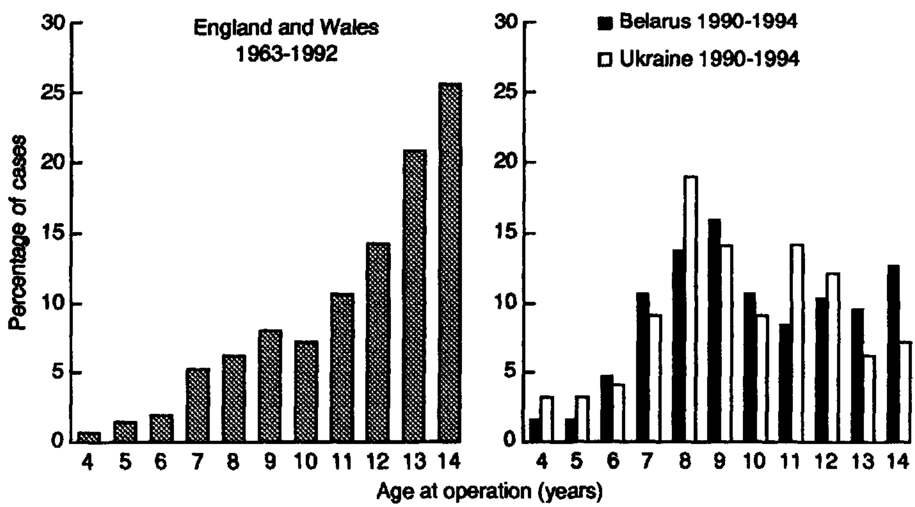

FIG. 3. Comparison of the age distribution of thyroid carcinoma in children (under 15 years at the time of operation) in England and Wales with those from Belarus and Ukraine.

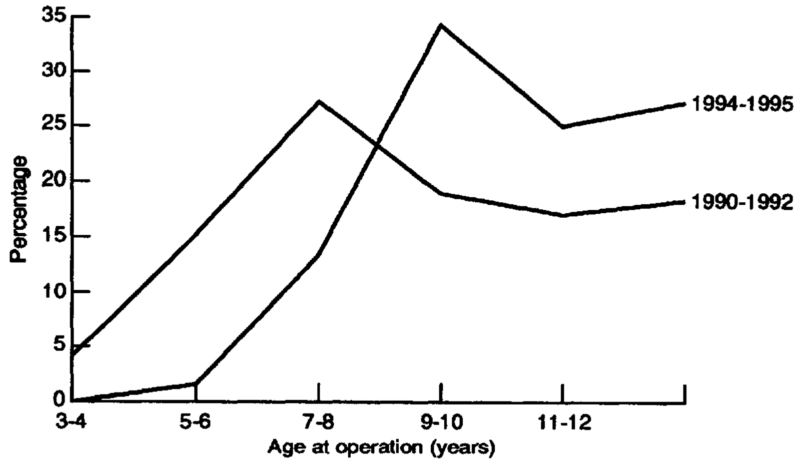

FIG. 4. Change in peak age at the time of operation for thyroid carcinoma in children in Belarus between 1990–1992 and 1994–1995.

period in England and Wales [16]. The ratio of observed to expected number of cases was highest in the children who were youngest at the time of the accident, and dropped rapidly with increasing age at exposure.

This higher sensitivity of very young children to the effects of radiation on the thyroid is consistent with observations of the higher sensitivity of young children to the carcinogenic effect of X radiation on the thyroid. The decrease in the likelihood of developing thyroid tumours with increasing age requires more observations for accurate quantification, but there is a considerable difference between newborn and 10 year olds. The observations also require extension into the adolescent age group. The reduction in sensitivity with increasing age is also consistent with the lack of any carcinogenic effect of ^{131}I treatment in adults with thyrotoxicosis, although other factors are also likely to be relevant.

Thyroid cancer in adults has been reported to have increased in frequency in the general population in Belarus since the Chernobyl accident, but the extent of the increase is very much smaller than in children and so far no international collaborative studies have been carried out on this problem.

There have also been reports of an increase in thyroid carcinoma incidence in liquidators, a group including some with high levels of exposure. These reports come from all three affected countries for this group of well monitored individuals.

This topic is discussed more fully in Background Paper 3, but the scale of the increase, if confirmed, is again very much smaller than that seen in the children.

2.7. Thyroid effects other than cancer

Several thyroid related effects of radiation exposure other than cancer are known to occur, of which the most obvious is the development of hypothyroidism after either external or internal radiation exposure at high levels. Radiation has also been associated with a transient increase in thyroid autoantibody production in patients treated with radioiodine for Graves disease [20]. Possible mechanisms for this include an increased release of antigens following tissue damage, and selective radiosensitivity of T suppressor cells in the thyroid. The Sasakawa Foundation study [19] carried out immunological investigations, measured antibodies to thyroglobulin and microsomes, and made functional assays measuring TSH and thyroid hormone (T4) levels as well as ultrasound studies. As far as possible, all investigations used similar equipment, staff were trained to a consistent level, and similar criteria were used to assign cases to appropriate groups.

Goitre occurs in areas where stable iodine intake is low. In this study, the 1994 report shows that the frequency of goitre in the five areas was highest in Kiev and lowest in Mogilev and Gomel. Nodules detected by ultrasound occur in areas of dietary iodide deficiency but can also occur following radiation exposure. The frequency of occurrence of thyroid nodules detected by ultrasound examination was variable, with the highest frequency of 188×10^{-4} found in Gomel, more than three times higher than the next highest, in Bryansk. Both antithyroglobulin and anti-microsomal antibodies were of fairly uniform prevalence in four of the areas, but in Zhitomir the prevalence of both antibodies was considerably increased.

Hypothyroidism can be caused by autoimmunity, can occur in cases of extreme iodide deficiency, and can also be caused by exposure to radiation at high levels. The prevalence of hypothyroidism, defined by a low T_4 and a high TSH, was particularly high in Gomel (34.6×10^{-4}). In the other areas it varied from 4.7×10^{-4} to 16.8×10^{-4}. The prevalence of hyperthyroidism in contrast showed much more consistency, ranging between 4.5×10^{-4} and 9.4×10^{-4} in the different areas. Iodide deficiency can lead to enlarged and nodular thyroids, but in this study the thyroid size was less in Gomel than in other areas, and it seems very unlikely that iodide deficiency was the main reason for the high frequency of nodules in Gomel. Radiation exposure can cause the development of thyroid nodularity and can also cause hypothyroidism.

The finding that both nodularity and hypothyroidism were more frequent in Gomel, the area with the highest exposures, while other conditions not related to radiation occurred at a broadly similar frequency in all areas, suggests that radiation may be linked to the high frequency of nodularity and hypothyroidism in Gomel.

3. DISCUSSION

The evidence presented shows clearly that there has been a major increase in histologically confirmed thyroid cancers in children in Belarus and Ukraine since the Chernobyl accident. A smaller increase has probably occurred in the Bryansk oblast in the Russian Federation, but firm population based evidence on the incidence of confirmed cases of childhood thyroid cancer is needed. The diagnosis of thyroid cancer has been confirmed in well over 90% of over 250 cases in both Belarus and Ukraine in an international co-operative study.

A major question in discussing the significance of the increase is how much could be attributed to increased ascertainment due to screening. The evidence that 'occult' microcarcinoma could have played a role has already been discussed. An additional significant point is shown in Fig. 3. The age distribution of thyroid tumours that would be expected from a screening programme in the absence of any other factor would parallel the age incidence seen in the non-exposed population, but with earlier diagnosis and smaller tumours. In fact, the age distribution in Belarus and Ukraine differed greatly from that seen in England and Wales, and from that reported in a number of cancer registries in various countries. It is not possible to do more than provide a rough estimate of the contribution that screening has made to the frequency of occurrence of thyroid cancer in children in Ukraine and Belarus, but the evidence available suggests that it is small.

The number of cases of childhood thyroid cancer that have occurred in Belarus and northern Ukraine between 1990 and 1994 is over 400. Of these, 315 occurred in Belarus, a country with about one fifth of the population of England and Wales; only about six cases would have been expected in Belarus if the incidence was the same as in England and Wales (0.5/million/year). The figures for the incidence of childhood thyroid cancer in Belarus and Ukraine in the years before Chernobyl are broadly similar to the rates for England and Wales. The crude rate for thyroid carcinoma in children in Gomel oblast for 1990–1994 approaches 200 times the rates for England and Wales. The incidence figures for England and Wales are towards the lower end of the range quoted for national tumour registries [14], but even if the pre-Chernobyl accident figures for Belarus underestimate the numbers several-fold, 315 cases represents a very large increase in this rare tumour. The most recent figures show that the incidence of thyroid carcinoma in children in Belarus continues to increase.

Ideally, the best evidence to throw light on the relationship of this increase to exposure to radiation as a result of the Chernobyl accident would come from a prospective study of a large number of children with measured exposures or, failing that, a retrospective case control study. Unfortunately, the numbers of children for whom there are accurate measurements is not large enough to allow any conclusions to be drawn at present, and the accuracy of retrospective dose reconstruction is uncertain. However, there is no doubt that in Belarus the Gomel oblast had higher radiation levels than the other parts of Belarus. The rates calculated for the Gomel oblast for childhood thyroid carcinomas over 1990–1994 inclusive are 92.0 per million per year, compared with 14.6 per million per year in the rest of Belarus.

As has been discussed, screening seems not to have made a major contribution to these figures, and while increased awareness generally by parents and medical staff may have contributed, the arguments that apply to the role of screening also apply to the role of increased awareness. There is therefore evidence that the high incidence of childhood thyroid cancer shows a broad correlation with radiation exposure in Belarus. Similar observations have been made in Ukraine [15].

As well as the geographical evidence correlating thyroid cancer incidence in children to exposure to radiation as a result of the Chernobyl accident, there is also temporal evidence. The increased incidence of childhood thyroid cancer drops dramatically in children born more than 6 months after the Chernobyl accident, to levels approximating those prior to the accident and those in other non-exposed countries. This holds true in both Ukraine and Belarus. In addition, the thyroid cancers found were almost exclusively papillary in type; the frequency of medullary and follicular carcinomas up to the present shows little if any increase over that seen in non-exposed populations. The type of thyroid cancers found in follow-up studies of children exposed to external radiation to the neck in infancy has been very largely but not exclusively papillary.

There are theoretical reasons why follicular carcinoma may appear later than papillary carcinoma following mutagen exposure, but, unfortunately, little detailed pathological assessment of thyroid carcinomas induced by external radiation has been carried out, and very few have occurred in children as young as those in Belarus and Ukraine. The excess of papillary carcinoma found is compatible with radiation induction. The geographical and temporal correlations with radiation exposure due to the Chernobyl accident provide compelling evidence that the increase in childhood thyroid cancer is causally related to this exposure.

A number of suggestions have been made about possible causes or contributory factors for the increase in thyroid cancer other than radiation exposure due to the Chernobyl accident. These include iodide deficiency, the administration of stable iodide after the accident, the eating of imported contaminated vegetables when local vegetables were declared unfit for consumption, industrial pollution generally and previous leaks from the plant. The dietary intake of stable iodide is related to thyroid carcinogenesis, but it appears to alter the type of tumour rather than lead to a major change in incidence [21, 22].

We cannot exclude the possibility that relative iodide deficiency may have played a role in increasing the uptake of radioactive isotopes of iodine during the period of exposure. The studies of the tumour incidence, and its relationship to age at exposure and age at operation all point to the cause being an agent that exerted its effect at the time of the Chernobyl accident and did not persist at a high level in the environment. While it is possible that there may have been earlier leaks of radioactive materials from the plant which may have contributed, the recorded incidence of childhood thyroid cancer in Belarus and in Ukraine as a whole before the accident was about the same as in England and Wales.

The possibility that chemical carcinogens may have contributed is again difficult to disprove. Both radiation and chemical carcinogens can give rise to thyroid tumours in animals but, given the lack of tumours in other sites and the type of thyroid tumour found, the carcinogen would have to be not only thyroid specific but also relatively specific for papillary carcinoma. No such carcinogen is known, except for radiation exposure of the thyroid.

The evidence that the increase in thyroid cancer is related to the isotopes of iodide deposited is again indirect. So far, no firm evidence is available of any attributable increase in the incidence of any malignancy other than thyroid cancer in the population exposed at high levels. Increases in the incidence in a range of tumours have been reported; however, the scale of the increase is very much less than that for the thyroid. As far as we are aware, the diagnoses have not been confirmed by an international group, and the size of the reported increase is in the range which may make it difficult to distinguish a true exposure related increase from an effect of better reporting and increased ascertainment. These reports are discussed in Background Paper 3.

It is important to establish whether there are increases in other tumours, but it is clear that no other tumour has shown an increase in incidence comparable with that seen for the thyroid. This makes it highly likely that exposure to radioactive isotopes of iodine was responsible for the increase in the incidence of thyroid cancer. Radioisotopes of iodine are known to have been deposited at high activity levels and, since they are very greatly concentrated in the thyroid gland, the radiation dose to the gland is many times that for other tissues.

The lifetime risk for the development of thyroid cancer is estimated as 0.8% per sievert, and the figures noted earlier for the levels of dose measured or estimated show that many children received doses higher than 1 Sv. The recent higher estimate of the amount of ^{132}Te released, and the consequent increase in the estimated activity levels of its decay product ^{132}I, may also be significant; and it may be relevant to the relatively lower increase in the incidence of childhood thyroid cancer in areas of the Russian Federation where ^{137}Cs was deposited at high activity levels.

Absolute proof of the causal relationship between exposure to radioiodine due to the Chernobyl accident and the increase in the incidence of childhood thyroid cancer is not available; however, the circumstantial evidence is very strong, and no other plausible explanation for the increase is available.

4. FUTURE PROSPECTS

The annual crude figures for the incidence of childhood thyroid cancer in Belarus and Ukraine provide a poor guide to the predicted numbers of thyroid cancers in the future. The figures show the incidence for children aged under 15 years, so that for each successive year, one exposed cohort is lost and is replaced by a cohort that was not born at the time of the Chernobyl accident. Figures from England and Wales show a smooth rise in incidence of thyroid carcinoma in children from about 6 years of age up to the age of 14.

Evidence from studies of thyroid cancer induced by external radiation suggests that the risk is multiplicative rather than additive [23]. If this is the case, then each cohort of exposed children should show an annual increase in incidence of thyroid carcinomas similar to the increase with age seen in England and Wales. Analysis of the data from nearly 300 cases from Belarus, observed over 5 years, shows that this does occur, with minor variations. When the observed figures in Belarus are compared with those expected based on the incidence in England and Wales, the sensitivity is found to be highest in children aged 0–1 year at exposure, and to drop rapidly with age at exposure. The rate of increase in incidence with age in many different registries, when pooled, is similar to that of England and Wales, so that although the ratio of observed to expected figures would change if a different country were chosen to provide the expected figures, the increased sensitivity seen in younger children as compared with older children would not change.

This increased sensitivity can be explained in pathological terms by the influence of post-mutational growth on the development of thyroid carcinoma, and in practical terms by the evidence that children under the age of four years have been shown to have five times the sensitivity to the carcinogenic effect of external radiation than older children [23] and the radiation dose to the thyroid from ^{131}I is about five times higher in infants than in older children [7, 24]. Many observations have found a higher sensitivity to the carcinogenic effect of radiation in young children, including the studies of the development of thyroid carcinomas in those exposed to radiation due to the atomic bombing of Japan, where the excess relative risk was about three times higher for children aged less than five years at exposure compared with those aged 10–19 years [25]. The observations explain the at first sight surprising age distribution of children with thyroid cancer in Belarus and Ukraine; this results from a combination of older children with a lower relative risk and younger children with a higher relative risk, giving a bell shaped curve, the peak of which moves up each year, and can be predicted to reach age 15 in the year 2001, then passing on into adolescence.

It is not possible to predict with certainty whether the relative risk will remain at its present figure; more than the present five years of observation are needed. The reasons for uncertainty include the possibility that children carrying genetic defects predisposing to tumour formation — for example DNA repair defects — will be more heavily represented in the early years, and their contribution will decline in later years, so that the relative risk is overestimated. It is also possible that follicular carcinomas have a longer latent period than papillary carcinomas, and that they may increase in incidence in later years; the relative risk would therefore be underestimated. Evidence from external radiation suggests that the relative risk increases up to 20 years after exposure, then declines, but that an increased risk is still present at 40 years after exposure [23]; and it would be prudent to make this assumption in considering the likely future rates of occurrence of thyroid carcinomas in the exposed population.

Significant exposure to radioiodine extended more than 100 km from Chernobyl, and for the designated 'contaminated' oblasts of Ukraine, Gomel, Brest and Mogilev in Belarus and Bryansk oblast in the Russian Federation, well over 3.5 million children were exposed. Within these areas there is a great variation in the estimated thyroid dose, ranging from less than 100 mGy to over 10 Gy, and, of course, the exposure was not confined to those oblasts only. The estimated mean dose for children in Minsk city, over 400 km from the Chernobyl plant, was 60 mGy, and an increased incidence in thyroid cancer has been recorded in a population exposed as children to as little as about 90 mGy of external radiation [26].

The accuracy of the estimated doses is difficult to assess; the contribution of short lived isotopes is probably not large, but no direct measurements of uptake were made. Many of the calculations rely on isotope ratios at different times during the accident, and the amount and ratios of isotopes released in the accident have recently been revised. It seems possible that around a million children received a thyroid dose of 500 mGy. The lifetime risk estimate for thyroid cancer can be calculated on the formula 0.8% per sievert; on this basis, about 4000 additional cases of thyroid cancer would be expected over the lifetime of these children.

An alternative method of predicting the expected numbers of thyroid carcinomas would be to relate it to the estimated thyroid dose and numbers of carcinomas observed in the Japanese follow-up study of atomic bombing victims. The predicted increase in thyroid carcinomas is presented in Table V of Background Paper 3. It can be seen that in Gomel oblast, using the pre-Chernobyl incidence, only five excess cases of thyroid cancer would be expected in the 10 years following the accident in children aged 0–14 years in 1986. These children would be aged 10–24 years at the end of the 10 year period.

If cancer incidence rates for the USA are used, 17 excess cases would be expected. Nearly 200 cases in fact occurred in children up to the age of 14 years in 1994 in Gomel during this period, considerably more have occurred in 1995 and 1996, and more again in those children from exposed cohorts who have developed thyroid carcinoma after the age of 14 years. The observed excess rate can be estimated to lie between 10 and 50 times the predicted excess rate. The reasons for the discrepancy include inaccuracies in dosage estimation, including the contribution of short lived isotopes, contributory factors of the type discussed earlier, and an underestimation of the effects of a combination of high radioiodine uptake in young children together with their inherent greater sensitivity to the carcinogenic effect of radiation. One point that needs further study is the possible role of genetic factors.

If the future risk is estimated on the basis of present trends in the exposed areas using a relative risk model, then the incidence of those exposed as children in Gomel will be about 200 times that of the United Kingdom. In a population of just over one third of a million, about five cases of thyroid cancer would be expected per year in adults in the United Kingdom; if the present ratio is maintained, this would give 1000 cases a year in the exposed cohort of children when they reach adulthood. If an additive risk model is used, the present excess of about 50 cases a year in Gomel will continue. It can be seen that there are many uncertainties, and an exact prediction of the expected numbers of thyroid carcinomas in the future is not possible. However, it would be prudent for advance planning of screening and health care to consider that a large increase is a possible outcome.

The evidence for thyroid effects other than carcinoma is limited. The reports of an increase in the number of nodules detected in the Gomel area as compared to other areas studied are relevant, particularly as the same area showed a high level of hypothyroidism but showed less goitre than other areas. Both nodules and hypothyroidism are known effects of radiation. Further work is needed to see if there is definitive evidence of an increase in nodules and in hypothyroidism in areas with high levels of radiation. It is worth noting that hypothyroidism has been recorded in horses left within the 30 km zone [7].

Thyroid carcinoma in adults is usually a tumour of relatively low malignancy, causing death in only a minority of cases. It is rather more aggressive in very young children [27], and a long follow-up period is needed. The number seen in Belarus and Ukraine constitutes a major challenge, both for treatment and for our understanding of the relation between exposure to radiation and the subsequent development of malignancy. The increased susceptibility of very young children to the subsequent development of thyroid carcinoma needs further study, but it may be possible to target screening to the cohorts most at risk. More accurate evaluation is needed, as this is important for ensuring that infants and small children are given the highest priority for protection in the event of any future accident. Studies of a possible increase in childhood thyroid cancer in countries where levels of radiation due to the Chernobyl accident were lower should also focus on the incidence in the cohort of children who were infants or small children at the time of exposure.

CONCLUSIONS

In conclusion, the present evidence on thyroid carcinomas in children in areas of Belarus, Ukraine and the Russian Federation where high radiation levels prevailed as a result of the Chernobyl accident has been reviewed. The pathological diagnoses have been confirmed, and the relationship to radiation exposure due to the Chernobyl accident has been confirmed through the geographical and the temporal distribution of cases. Screening has not made a major contribution to the number of cases observed.

The pathology of the cases shows papillary carcinomas, many with an unusual solid/follicular pattern of growth. The molecular biology of the cases so far studied has not shown any major differences from tumours of the same type in thyroids not exposed to radiation, although it remains possible that the different types of ret translocation may differ in frequency. Analysis of the data on age at exposure and age at operation for the Belarus cases is compatible with a relative risk model of carcinogenesis. Comparison of the data with those from a study of childhood thyroid cancer in England and Wales suggests that children aged under one year at exposure are considerably more susceptible than other children. If this high relative risk persists, there would be a very large increase in the incidence of thyroid carcinoma in the next century in adults who received high radiation doses as children owing to the Chernobyl accident. Further studies are needed to follow the occurrence of thyroid carcinoma, together with epidemiological studies to gain more information, on the basis of which accurate risk estimates and accurate forecasts of the likely future incidence of thyroid carcinoma may be made. These studies must be linked to humanitarian support in treating cases of thyroid carcinoma and in assisting any possible preventive measures, including targeted screening of the cohorts with the highest risk.

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DISCUSSION ON BACKGROUND PAPER 2

F.A. METTLER (United States of America): Much of the increase in the incidence of thyroid cancer following the Chernobyl accident could have been prevented through the administration of potassium iodide. I should be interested in hearing comments on this issue.

D.A. BECKER (United States of America): Certainly the administration of potassium iodide before the accident or within 6–12 hours after it would have greatly reduced the radiation dose delivered to the thyroid by radioiodine. Many governments — especially in Europe — have therefore decided that stocks of potassium iodide should be built up and maintained. In the United States of America, on the other hand, the Nuclear Regulatory Commission has not recommended the creation of such stocks.

A. PINCHERA (Italy, Chairperson): Iodine prophylaxis has been recommended in several WHO reports, which have given details — with special reference to risk groups — of the doses which should be administered in the light of the recipient's age and sex and of other conditions.

J.A. NAUMANN (Poland): Following the Chernobyl accident, potassium iodide was administered (as a mandatory measure in the case of children) to about 18 million people in Poland. The result was a 25–40% (depending on the date of administration) lower final committed thyroid dose.

While I have the floor I should like to ask whether, in addition to iodine-131, short-lived radioisotopes of iodine (for example, iodine-132) — which were released in fairly large amounts during the Chernobyl accident — contributed to the final committed thyroid dose.

A. PINCHERA (Italy, Chairperson): In my view, it is likely that they contributed something, but the present data do not allow us to say how much. This is a matter on which more information is needed.

C. ZUUR (Netherlands): I believe very much in the value of iodine prophylaxis, but I am worried about the possibility of side-effects and wonder whether the advantages of iodine prophylaxis may not be outweighed by the disadvantages when intervention levels are as low as 50 mSv.

I understand that the administration of iodine can lead to an allergic reaction in people who are subsequently subjected to X ray examinations with the use of contrast media. Also, I understand that there can be side-effects after many years of thyroid hypofunction.

A. PINCHERA (Italy, Chairperson): This matter has been fairly well covered in reports issued — with recommendations — by WHO and the European Commission.

F.A. METTLER (United States of America): There is nothing about dose-response relationships in the Background Paper, and clearly dosimetry was a problem. In dosimetry, especially with children, account should be taken of thyroid size, iodine turnover and iodine uptake. Would anyone care to comment on the issue of dose-response relationships?

A. PINCHERA (Italy, Chairperson): Perhaps Prof. Nagataki would comment.

S. NAGATAKI (Japan): There is strong geographical and chronological evidence that the cases of thyroid cancer detected in the areas affected by the Chernobyl accident are due to the accident, but we realize that we do not have a dose-response relationship for thyroid cancer.

A. PINCHERA (Italy, Chairperson): Thank you Prof. Nagataki. I think it can be said that, apart from thyroid cancer, there are no lesions which can be related to radiation exposure of the thyroid and that hypothyroidism is induced by autoimmune reactions.

As far as the Chernobyl accident is concerned, there are no reliable dosimetry data. Perhaps Prof. Becker would care to say a few words about that.

D.A. BECKER (United States of America): Enormous efforts have been made to determine the radiation dose received by the affected population, particularly in support of epidemiological studies, through which we hope to obtain a correlation between the radiation dose delivered to the thyroid and the subsequent appearance of thyroid cancer in the long term.

Cohort studies are dependent on radiation dose estimates, but the radiation exposure depends on the amount of radioactivity taken up by the thyroid, the size of the thyroid and the turnover of radioiodine by the thyroid.

Thyroid uptake was measured for a substantial number of people, although not as many as we would have liked. It is influenced by many factors, such as the location of the individual at the time of the accident and his/her age at that time (since age is directly related to thyroid size).

The dose reconstruction work under way in many places is being carried out by a large number of experienced dosimetrists, but the associated errors are still substantial. It should be remembered, however, that the dose reconstructions for Hiroshima and Nagasaki have undergone three major revisions during the past 50 years and that the associated errors have been reduced to something like 30–40% from the initial values, which were probably about 200–300% — similar to the probable initial values following the Chernobyl accident.

J.S. NATHWANI (Canada): Is it possible at this stage to make a precise quantitative link between the increased incidence of thyroid cancer in children and increases in mortality?

A. PINCHERA (Italy, Chairperson): As indicated in the Background Paper presented by Prof. Williams, papillary thyroid carcinoma in adults is usually a tumour of fairly low malignancy. In spite of its relative aggressiveness, papillary thyroid carcinoma occurring in children is susceptible to treatment, and most patients can look forward to a normal life expectancy, provided that appropriate therapeutic measures are applied. So far, very few children have died of the disease. From the short-term follow-up data available at present, it would appear that the children with post-Chernobyl thyroid cancer respond favourably to standard therapeutic procedures. Unquestionably, careful and close monitoring of these patients is required in order to ensure the success of the treatment. The monitoring of subjects who were very young children at the time of exposure should also be carried out in order to detect the disease at an early stage. At present, it would appear that deaths from thyroid cancer will not be a major factor in decreasing life expectancy as a result of the Chernobyl accident.

P.V. RAMZAEV (Russian Federation): I should like to add to what Prof. Tsyb said yesterday about the situation in the Russian Federation regarding thyroid cancer.

Figures 1 and 2 give a comprehensive picture of the dynamics of the incidence of thyroid cancer for adults and children and for contaminated and clean areas.

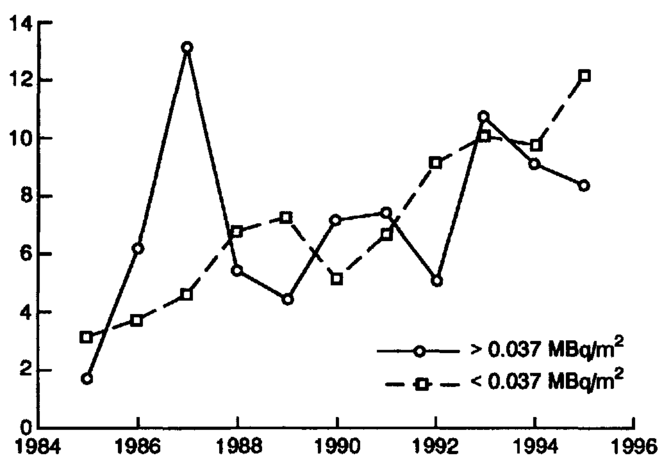

FIG. 1. Thyroid cancer incidence in the "adults-86" population in settlements with different levels of ^{137}Cs soil contamination in the Bryansk region, per 100 000.

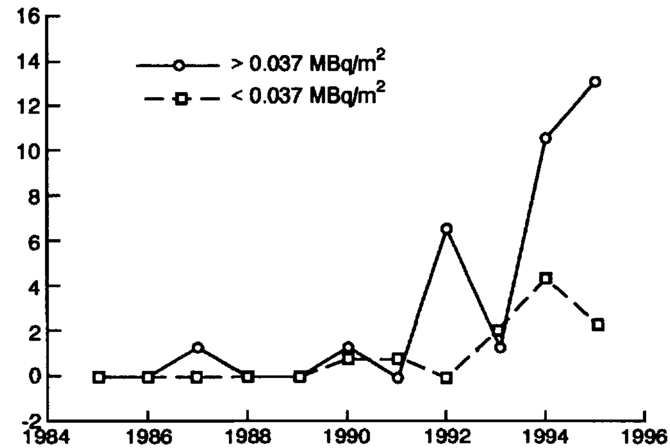

FIG. 2. Thyroid cancer incidence in the "children-86" population in settlements with different levels of ^{137}Cs soil contamination in the Bryansk region, per 100 000.

As regards Fig. 1, which relates to adults, there were in the Bryansk region 852 cases of thyroid cancer during the ten years following the Chernobyl accident. As you can see from the solid curve, in the Bryansk region we had a sixfold increase in the incidence of thyroid cancer in contaminated areas immediately after the accident. At that time, hundreds of additional physicians helped in detecting cases of thyroid cancer. Then the curve for the contaminated areas dipped, after which there were broadly similar increases for the contaminated areas and the clean areas.

As regards Fig. 2, which relates to children, there has been a steady increase in the number of thyroid cancer cases, the greatest increase occurring in the contaminated areas.

Turning to the question of public health care, I would mention that the number of thyroid cancers among adults rose by 467 and that of thyroid cancers among children rose by 55. Consequently, our surgeons are having to devote eight times more effort to dealing with adults than to dealing with children.

In the light of the experience of the past two years, we believe that the thyroid cancer cases are due to radiation. However, there is not a close correlation; the correlation factor is only +0.40.

A.F. TSYB (Russian Federation): During the past year and a half, at conferences like those held recently in Geneva and Minsk, Russian experts have been presenting data on the incidence of thyroid cancer in the Russian Federation following the Chernobyl accident. Accordingly, I cannot understand why people say that such data are not available.

The present situation in the Russian Federation is as follows. In the four most contaminated oblasts (Bryansk, Kaluga, Tula and Orel), we have 104 cases of thyroid cancer among individuals who were 0–14 years of age at the time of the Chernobyl accident — a fairly large number. The cancers appeared much earlier among the girls (after 1–2 years) than among the boys (after 3–4 years).

I should like to draw attention to one particular cohort of 10 000 children — in the Kaluga oblast — for whom we have accurate individual dose measurements. The doses are low (lower than in the Gomel oblast), being clearly dependent on the distance from the Chernobyl NPP, and over the past ten years we have found only four cases of thyroid cancer.

I think it would be interesting to combine the data on those cohorts of children for whom we had dose values which we know are accurate to within, say, 30%, and to determine the incidence of thyroid cancer among them. In Ukraine, for example, a large number of direct dose measurements have been performed on children.

In the near future, I shall be presenting new data on a group of about 50 000 children, aged up to 14 years, in every fifth or sixth of whom we have found small (less than 1 cm across) nodular formations. These may be hidden cancers which are being discovered with the help of ultrasonic and other new techniques. Certainly they raise a large number of questions, which we should like to see cleared up.

E.D. WILLIAMS (United Kingdom, Scientific Secretary): In response to what Prof. Tsyb just said, I would emphasize that thyroid cancer data from the Russian Federation were not deliberately ignored; however, only data from those countries which have agreed to abide by internationally accepted uniform diagnosis standards were presented. The data from Belarus and Ukraine relate to all cases of childhood thyroid cancer in those two countries, whereas the data from the Russian Federation relate to only a very small number of cases.

Moreover, the more than 100 cases mentioned by Prof. Tsyb relate to persons who were up to 25 — rather than 15 — years of age at the time of diagnosis, so that the figures given by him are not comparable to the figures quoted for Belarus and Ukraine.

As the number of spontaneous cases of thyroid cancer rises rapidly with increasing age, one needs to know how many cases would be expected in a non-radiation-exposed population before one can interpret the data.

Data on the incidence of thyroid cancer in the exposed population in the Russian Federation are extremely important for completing our understanding of the effects of the Chernobyl accident on the thyroid, and we look forward to collaborating with Prof. Tsyb in this connection. At all events, so far, the number of cases of thyroid cancer in individuals aged 14 years or less at the time of diagnosis seems to be much lower in the Russian Federation than in Belarus and Ukraine.

L.V. REMENNIK (Russian Federation): Data on the incidence of thyroid cancer in Russia are presented in poster paper CN-63/370 prepared by members of the P.A. Herzen Cancer Research Institute, Moscow. At the Institute we have, for all parts of Russia, data on children aged 0–14 years, on cohorts of individuals exposed at ages in the range 0–20 years and on the adult population. Our data are qualitatively similar to the Ukrainian data, even our data on the ratio of the number of morphological forms of thyroid cancer.

E. CARDIS (France): I should like to make a comment about the risk predictions presented by Prof. Williams.

These were made by using a relative risk model, but on the basis of age-specific radiation-induced thyroid cancer risk estimates derived from atomic bomb attack survivors and other populations of exposed children.

On that basis (as I shall show when presenting the Background Paper for Topical Session 3), for the Gomel oblast the predicted total number of thyroid cancer cases in the first ten years after the Chernobyl accident among individuals exposed as children (0–14 years of age) is about 38, even with the high estimates of risk. Of these cases, only about one half (i.e. 20) would be diagnosed during childhood.

What had actually been observed in the Gomel oblast by the end of 1995 was about 200 cases, which is ten times as high as our highest predictions.

There is clear evidence that the very large increase in the incidence of childhood thyroid cancer in the affected countries is related to iodine isotopes from the Chernobyl accident, but the extent of the discrepancy raises the question whether the discrepancy is due to serious underestimation of the dose from iodine-131, to the shorter-lived isotopes of iodine and tellurium or to a factor or combination of factors modifying the risk of radiation-induced cancer — including age at the time of exposure (about which there is no uncertainty), iodine deficiency and supplementation (which may affect radioiodine uptake and also — following exposure — thyroid function), and possibly genetic predisposition (several families with two children suffering from thyroid cancer have been found in Belarus, and studies pointing to a radiation-induced thyroid cancer risk 3–10 times higher in the case of Jewish children suggest that genetic predisposition may be related to ethnic origin).

This question should be studied, for the answers could have important implications for the protection of populations in the event of further incidents involving major environmental exposures and for the protection of patients undergoing radiotherapy.

R. HOCK (Germany): With regard to the short-lived isotopes of iodine, I would mention that, on the third and fourth days after the Chernobyl accident, as we had no information about what was happening at Chernobyl, we carried out a very thorough analysis of the composition of the nuclides which we could measure in Germany. On the basis of that analysis I concluded that a chain reaction was still taking place in the damaged reactor. This conclusion was later rejected in the light of information received from the site, but the fact that boron was being dropped onto the reactor suggests that other people also believed that a chain reaction was still taking place — or that the chain reaction might restart.

A continuing or resumed chain reaction with an undelayed release of iodine would lead to a tremendous increase in the amounts of short-lived isotopes in the environment, and I should be interested in hearing why this possibility is rejected.

I. LIKHTAREV (Ukraine): The matter of short-lived iodine isotopes was considered in detail in Chernigov about five years ago, when it was shown that in towns like Pripyat, where foodstuffs were significant as regards iodine uptake, short-lived isotopes could be important. Even in such towns, however, about 50% of the thyroid dose was due to the activity of iodine-131 through inhalation.

As regards other areas, in 95% of the cases no more than 5% of the thyroid dose was due to short-lived isotopes (mainly iodine-133).

I am surprised that this matter — which was resolved some time ago — is being raised again.

A. PINCHERA (Italy, Chairman): I understand from what has just been said that short-lived iodine isotopes were present but their contribution, except for the individuals living in the vicinity of the Chernobyl NPP, was very small.

Th. ABELIN (Switzerland): There has been a large increase in thyroid cancer incidence rates in a part of Brest oblast about 270 km west-north-west of Chernobyl, with about 30 cases reported each year. The increase, which started later than the increase in Gomel oblast, needs to be explained.

In this connection I would mention the question of estimates of radioiodine contamination which are based on meteorological observations. It appears that immediately after the start of the Chernobyl accident there was a strong wind in the Chernobyl area blowing in a north-north-westerly direction, and it is possible that the areas first reached by fallout received considerable doses due to short-lived iodine isotopes. As it is very difficult to reconstruct the dose rates now, I think use should continue to be made of meteorological information with a view to gaining a better insight into the possible role of short-lived iodine isotopes in the development of Chernobyl-related thyroid cancer.

M. GEMBICKI (Poland): Iodine deficiency in the regions affected by the Chernobyl accident has been mentioned as a major factor contributing to the incidence of different thyroid diseases, including thyroid cancer, in those regions.

In that connection, I should like to mention that, some time ago, together with Prof. Stozharov of the Institute of Radiation Medicine in Minsk, I initiated, on behalf of WHO, an epidemiological study of the iodine deficiency situation in Belarus.

In the pilot stage of the study, which involved 1000 children from both urban and rural areas, we found that only 25% of the children had excretion rates of iodine in urine higher than 100 μg/L and that over 50% had iodine excretion rates less than 50 μg/L.

W. PAILE (Finland): It appears that the administration of a single dose of stable iodine to some ten million children produced no serious side-effects, so I think we can forget about the risk of side-effects in children.

In my view, provided the social and economic costs of stable iodine administration are low, which they are when tablets containing stable iodine have been predistributed to strategic points, there is no reason for not having an intervention level as low as 10 mGy in the case of thyroid doses for children. Such an intervention level could prevent a two- to fivefold increase in thyroid carcinoma rates for children.

Th. ABELIN (Switzerland): A close look at the geographical distribution of the incidence rates for thyroid cancer among Belarus children and adolescents reveals that among individuals who were 0–15 years old at the time of the Chernobyl accident an increase in the incidence of thyroid cancer occurred not only in the districts directly adjacent to the accident site, but as far as — or even further than — 250 km away. I think this should be taken into account in plans for the prophylactic distribution and administration of stable iodine where nuclear installations exist.

TOPICAL SESSION 3

Long Term Health Effects

Chairperson	R.H. CLARKE, United Kingdom
Vice-Chairperson	A. OKEANOV, Belarus
Scientific Secretary	R. SCHMIDT, WHO
Rapporteur	E. CARDIS, IARC
Expert Committee	L. ANSPAUGH, United States of America V. IVANOV, Russian Federation I. LIKHTAREV, Ukraine K. MABUCHI, Japan A. OKEANOV, Belarus A. PRISYAZHNIUK, Ukraine

ESTIMATED LONG TERM HEALTH EFFECTS OF THE CHERNOBYL ACCIDENT

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Abstract

ESTIMATED LONG TERM HEALTH EFFECTS OF THE CHERNOBYL ACCIDENT.

Apart from the dramatic increase in thyroid cancer in those exposed as children (see Background Paper 2), there is no evidence to date of a major public health impact as a result of radiation exposure due to the Chernobyl accident in the three most affected countries (Belarus, Russia and Ukraine). Although some increases in the frequency of cancer in exposed populations have been reported, these results are difficult to interpret, mainly because of differences in the intensity and method of follow-up between exposed populations and

the general population with which they are compared. If the experience of the survivors of the atomic bombing of Japan and of other exposed populations is applicable, the major radiological impact of the accident will be cases of cancer. The total lifetime numbers of excess cancers will be greatest among the 'liquidators' (emergency and recovery workers) and among the residents of 'contaminated' territories, of the order of 2000 to 4600 among each group (the size of the exposed populations is 200 000 liquidators and 6 800 000 residents of 'contaminated' areas). These increases would be difficult to detect epidemiologically against an expected background number of 41 500 and 800 000 cases of cancer respectively among the two groups. However, the exposures for populations due to the Chernobyl accident are different (in type and pattern) from those of the survivors of the atomic bombing of Japan (and doses received early after the accident are not well known). Predictions derived from studies of these populations are therefore uncertain. Indeed, although an increase in the incidence of thyroid cancer in persons exposed as children as a result of the Chernobyl accident was envisaged, the extent of the increase was not foreseen. Only ten years have passed since the accident. It is essential, therefore, that monitoring of the health of the population be continued in order to assess the public health impact of the accident, even if any increase in the incidence of cancers as a result of radiation exposure due to the Chernobyl accident, except for leukaemia among liquidators and thyroid cancer, is expected to be difficult to detect. Studies of selected populations and diseases are also needed in order to study observed or predicted effects; careful studies may in particular provide important information on the effect of exposure rate and exposure type in the low to medium dose range and on factors which may modify radiation effects. As such, they may have important consequences for the radiation protection of patients and the general population in the event of any future accidental exposure.

1. THE ISSUES

Ionizing radiation is one of the best studied carcinogens in the human environment. Hundreds of thousands of persons exposed to radiation around the world (survivors of the atomic bombing in Japan, patients irradiated for therapeutic purposes, workers exposed occupationally) have been followed up for decades. Many large scale animal experiments have been carried out and much experimental work has been performed to understand the mechanisms of radiation damage at the cellular and molecular level and quantify its effects. The major long term effects identified [1–5] are an increase in the frequency of cancers and cataracts and, among those exposed in utero, a higher frequency of congenital anomalies. A small increase in hereditary effects has also been observed in animal experiments.

Predictions concerning the likely radiological consequences of the Chernobyl accident have been made on the basis of these data. Much of the data accumulated to date, however, are from studies of populations that have received relatively high doses in an acute or fractionated fashion, often from external radiation. Uncertainties remain concerning the exact magnitude of the health effects of the exposures received by populations as a result of the Chernobyl accident, in particular:

(a) the effects of relatively low doses[1], such as those resulting over large areas following the Chernobyl accident;
(b) the effects of protracted (chronic as opposed to acute) exposures, such as were received by populations exposed environmentally and by some of the liquidators[2];
(c) the effects of different radionuclides and different radiation types;
(d) the effects of factors which may modify radiation induced risks (including age at exposure, sex, possible genetic predispositions and other host and environmental factors).

Ten years have now passed since the Chernobyl accident and it is timely to summarize what long term health effects have been observed up to now, whether they agree with predicted effects and what might be expected to be seen in coming years and decades. In this Background Paper the organization of the epidemiological follow-up of exposed populations in the three most affected countries (Belarus, the Russian Federation and Ukraine), the levels of radiation doses they received, the health consequences expected on the basis of previous epidemiological studies of populations exposed to radiation, and the main results to date are reviewed. Four groups of exposed populations (see Table I) are considered separately, where possible:

1. The 600 000–800 000 'liquidators' (also referred to as cleanup or recovery workers): this includes persons registered as having participated in the cleanup after the accident (cleaning up the plant and its surroundings, construction of the sarcophagus, decontamination, building of roads, destruction and burial of contaminated buildings, forests and equipment), as well as many others, including physicians, teachers, cooks and interpreters who worked in the 'contaminated' territories. Among them, approximately 200 000 worked in 1986–1987, when the exposures were more significant.
2. The 'evacuees': those who were evacuated from the town of Pripyat and the 30 km zone around the Chernobyl plant in April–May 1986;
3. The residents of the 'strict control zones' (SCZs): those members of the general population who have continued to live in the more heavily contaminated areas (with a level of ^{137}Cs deposition greater than 555 kBq/m^2), typically within a few hundred kilometres of the Chernobyl plant. Within these areas, radiation monitoring and preventive measures have been taken to maintain doses within permissible levels.
4. The general population of the 'contaminated' territories in the three countries.

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[1] In the range of 0–300 mSv over a lifetime.

[2] Results from experiments with animals suggest that the risk per unit dose is lower for protracted (chronic) exposures than for acute exposures.

The primary focus of this Background Paper is the estimation of the burden of cancer resulting from the accident: the major long term effect expected on the basis of studies for high doses. Thyroid cancer, which has been observed to increase dramatically in children exposed at the time of the accident, is discussed in more detail in Background Paper 2. It is too early to assess genetic effects, and the absence of systematically collected data on genetic and other effects (cataracts, congenital anomalies) in most of the affected countries make it difficult to draw any conclusions about these. In comparison with other European countries, relatively high levels of contamination were recorded in Bulgaria, Austria, Greece and Romania, followed by other countries of central, south-east and northern Europe. However, effects of radiation exposure due to the Chernobyl accident outside the three countries most affected are not discussed, since both the levels of exposure and the magnitude of the effects to be expected to date are very low [6–8]. Acute effects of radiation exposure are discussed in Background Paper 1.

2. BACKGROUND

2.1. Background scientific knowledge about radiation risks

Ionizing radiation is one of the agents in the environment for which genetic and cancer risks have been best studied and characterized. This is mainly due to two facts: (1) very large numbers of exposed persons have been followed up for decades; and (2) exposures to radiation, unlike for many other environmental agents, are relatively easy to reconstruct, and doses to measure, on an individual level, at least for radiation exposures at high dose rates and high doses. The information available to date on radiation risks comes from several sources:

- epidemiological studies of large populations that have received relatively high doses of gamma or X radiation at a high dose rate (survivors of the atomic bombing, patients treated by radiotherapy for malignant or benign diseases) or doses due to radon protracted over many years (hard rock miners, particularly uranium miners) [1, 9, 10];
- more recently, large scale epidemiological studies of populations having received low doses in a protracted fashion as a result of their occupation, mainly in the nuclear industry [11, 12];
- large scale animal experiments carried out in order to understand the effects of different radiation types, exposure levels, patterns of exposure and modifying factors [1, 9, 10];
- cytogenetic, molecular and genetic studies aimed at understanding the mechanisms of radiation induced carcinogenesis [2, 9].

The major long term effects identified [1–5] are an increase in the frequency of cancers, particularly leukaemia, and of cataracts and, among those exposed in utero, a higher frequency of congenital anomalies. A small increase in genetic effects has also been observed in animal experiments.

The temporal patterns of radiation risks have been observed to differ markedly for leukaemia and solid cancers. In the follow-up of the survivors of the atomic bombing, excess risk for leukaemia increased sharply after the bombing, reaching a peak 3–10 years after exposure, followed by a gradual decline [13]. The temporal pattern of leukaemia risk was markedly modified by age: in general, the younger the age at exposure, the higher the initial excess risk and the steeper the subsequent decline. Among those exposed as adults, the decline was less pronounced for women than men.

The excess solid cancer risk, however, appeared gradually, starting 5–10 years after exposure, and increased roughly in proportion to the background cancer rates (these typically increase with advancing age). The excess relative risk (i.e. the proportional increase in risk relative to background risk) for solid cancers depended on age at exposure and sex. It was generally higher for those exposed at younger ages and for women. The temporal pattern of the relative risk has been remarkably constant during the follow-up [14], except for those exposed early in life, for whom the relative risk has been decreasing with the passage of time. Thyroid cancer risk has followed a similar temporal pattern [15]. A recent pooled analysis of seven studies suggests that the excess relative risk of thyroid cancer among those exposed as children (below the age of 15 years) remains elevated for many years, declining only 30 years after exposure [16].

2.2. The follow-up of populations exposed to radiation as a result of the Chernobyl accident: organization and problems

2.2.1. Chernobyl Registry follow-up

The Chernobyl Registries were established initially as a single 'All-Union Distributed Registry' located in Obninsk, Russia, by a 1987 directive of the Ministry of Public Health of the USSR [17]. The aim was to set up a comprehensive registration and follow-up system for the persons most affected by the Chernobyl accident. The directive identified four groups of subjects — the groups of 'primary registration' — for whom registration and 'active' follow-up was mandatory: participants in the 'liquidation' of the consequences of the Chernobyl accident, the so-called 'liquidators'; subjects evacuated from the most contaminated territories (>1480 kBq/m^2); persons living in 'contaminated' areas (>555 kBq/m^2); and children of the above groups. Since the dissolution of the USSR, the responsibility for the State Chernobyl Registries has been passed to the individual countries.

As a consequence of this directive, all persons included in the State Chernobyl Registries are 'actively' followed up: they must undergo an annual medical examination in which they are systematically examined by a general practitioner and a number of different specialists. The persons are also directed, as appropriate, for additional examinations to oncologists and other specialists.

All data on diseases diagnosed during the annual medical examination, as well as in local clinics at any other time during the year, are sent to the Chernobyl Registries for inclusion in the registry database. In addition to medical data, the State Chernobyl Registries include demographic variables, information on location and behaviour (food and milk consumption, time spent in 'contaminated zones') at the time of the accident and on work in the Chernobyl area, and, when available, dosimetric information.

2.2.2. *Monitoring of the health of the general population*

Means are also available in the affected countries to carry out 'passive' follow-up of exposed persons and of the general population with the use of population registries — of mortality, cancer and other diseases.

Mortality

In each country of the former USSR, population registration is carried out at the local level in the address bureaux (where the addresses of present residents are kept) and the ZAGS (buro zapicii akta grazhdanskovo sostoyania, which compile all information about birth, marriage, divorce and death of persons living in the administrative area). There is no centralized registry, however, and results of a recent pilot study [18] indicate that considerable time and effort may be needed for tracing subjects who have moved from one area to another. In Belarus, centralization of population registry data is under way; this will increase the feasibility of mortality follow-up of populations. Little information is available currently, however, on the adequacy of mortality data in the affected states.

Cancer incidence

A computerized national Cancer Registry has been functioning in Belarus since the 1970s and registers all cases of malignant neoplasms. A comprehensive registry of haematological diseases also exists in Belarus, in the Institute of Haematology and Blood Transfusology, and a registry of childhood thyroid cancer cases in the Institute for Thyroid Pathology in Minsk, where most of these tumours are operated. These registries have proved to be valuable tools for epidemiological follow-up in Belarus [19–23]. They may, however, all be improved with the adoption of international standards for coding, classification and quality control.

In Russia and the Ukraine, no centralized cancer registration system was in place at the time of the accident. Work is under way in both countries to set one up — at least in 'contaminated' areas in Russia [20]. At present, however, routine data on cancer morbidity in these countries are obtained from local oncological dispensaries and verification of the completeness and accuracy of the diagnosis information and checks for duplication are not systematically performed. For persons included in the Chernobyl Registry, moreover, information on cancer diagnosis is often obtained from the records of medical visits in local medical centres; if a patient is referred to the regional or national level for confirmation and treatment and the diagnosis is changed, the information is not necessarily sent to the Chernobyl Registry. A recent study of leukaemia among liquidators in Russia [18] confirms that the diagnostic information in the Chernobyl Registry is not always accurate. The lack of verification and quality control is actively being remedied. However, this lack must be kept in mind when interpreting results of studies of cancer incidence among exposed populations in those countries.

General morbidity

Information is also available systematically on the general (i.e. not only cancer) morbidity of the population of the three countries. In the countries of the former USSR, regional out-patient clinics systematically collect information on disease diagnoses for all the residents of the region that they cover (not only on those included in the Chernobyl Registry). This information is summarized locally and is sent, on special statistical reporting forms, at yearly intervals to the Ministry of Health. These forms contain information about the number of cases of acute and chronic diseases diagnosed in a given year in the population in all areas of the country. This information is not broken down by age or sex. No verification of completeness or checking for duplication is possible. This passive system of collection of morbidity data on the population contrasts with the active follow-up carried out, as described earlier, for persons included in the Chernobyl Registry. Comparisons of morbidity based on these sources must therefore be interpreted with caution.

2.2.3. *Ad hoc studies*

A number of factors limit the power of the routine follow-up activities listed above to detect the expected effects of exposure due to the Chernobyl accident, even in the three most affected countries. They include, in particular: the generally low radiation doses received by the majority of exposed populations — and hence, presumably, the low level of risk expected; the difficulties of systematic and complete follow-up; the lack of precise dosimetry (as described in the following); and the movements of populations which have taken place since the accident.

Ad hoc analytical epidemiological studies, focusing on specific diseases and populations, may be a more useful approach for investigating the effects of radiation among the exposed populations [24, 25]. Cohort studies of well defined populations — i.e. studies of groups of individuals who are followed over time, for example the cohort of all children whose thyroid dose was reconstructed from direct measurements made in the days following the accident — are important tools for studying radiation effects if precise individual dose estimates can be obtained and if a systematic and complete follow-up can be achieved. When this is not feasible for logistical and/or financial or other reasons, case control studies, i.e. studies of cases of a disease of interest occurring in a given population (such as cases of leukaemia occurring among liquidators) together with studies of appropriate controls, are a cost efficient and powerful alternative. This type of study allows the collection of relatively detailed individual information on the exposure of interest and on other risk factors (from questionnaires as well as from searches of existing records) at much lower cost since the number of study subjects is much reduced.

Both cohort and case control studies are generally much more powerful than descriptive studies for investigating dose relationships. Indeed, the single most informative study on radiation risks today, that of the survivors of the atomic bombing of Hiroshima and Nagasaki [14], would have provided much less information concerning the relation between radiation exposure and cancer risk if the follow-up had been restricted to an examination of trends of diseases over time and comparisons with non-exposed persons or the general population.

2.3. Radiation doses to different groups: dose levels and available estimates

Table I presents a summary of the number of persons exposed and the levels of doses received in the four groups described earlier. Much effort has been directed to reconstructing doses on an individual or group level for liquidators and for populations exposed environmentally, mainly for those who were at the time of the accident living in the areas that became most 'contaminated' [26–33]. Less attention has been focused on reconstructing dose levels for the general population living in 'contaminated' territories outside the 'strict control zones' and 'evacuation zones' since, given the level of dose they received, it is unlikely (if our current estimates of risk are correct) that any radiological effect on health could be detected in this population, even though it may well have received the largest total collective dose.

Radiation doses for these populations have been estimated in a variety of ways: from direct whole body or thyroid counting (to determine, respectively, the individual body burden and thyroid burden from various radionuclides) and physical measurements of doses due to external irradiation with individual dosimeters, to dose reconstruction using environmental models and questionnaires, and to estimation of dose using biological or biophysical markers of exposure. The accuracy of the dose estimates varies according to the estimation method and the level of dose (for example, more precise and numerous measurements were made in the most contaminated regions).

2.3.1. Liquidators

Approximately 600 000 to 800 000 persons were registered as having been involved in the cleanup activities to 'liquidate' the consequences of the Chernobyl accident. This includes persons who participated in the cleanup after the accident (cleaning up around the reactor, construction of the sarcophagus, decontamination, building of roads, destruction and burial of contaminated buildings, forests and equipment), as well as many others, including physicians, teachers, cooks and interpreters who worked in the 'contaminated' territories and received on average much lower doses. Approximately 200 000 liquidators (see Table I) worked in the region of Chernobyl during the period 1986–1987, when the exposures were more significant.

The dosimetric information available on liquidators is subject to controversy, since the personal dosimeters in use in the early days after the accident were too few and generally too limited in range. A reasonable estimate of the average dose received by the 200 000 liquidators from 1986 to 1987 is 100 mSv [28]. Thus the collective effective dose would be approximately 20 000 man·Sv. It is noted that some workers received their dose in a matter of minutes — for example working on the roof of the reactor — while others received it over months or even years, and the predominant radiation type and route of exposure varied according to time and to the activities of the liquidators.

TABLE I. ESTIMATES OF COLLECTIVE EFFECTIVE DOSES FOR POPULATION GROUPS OF INTEREST

Population	Number	Collective effective dose (man·Sv)
Liquidators (1986–1987)	200 000	20 000
Evacuees	135 000	1 600
Persons living in 'contaminated' areas[a]		
Deposition density of ^{137}Cs > 555 kBq/m^2	270 000	10 000–20 000
Deposition density of ^{137}Cs > 37–555 Bq/m^2	6 800 000	35 000–100 000

[a] These doses are for 1986–1995; over the longer term (1996–2056), the collective dose will increase by approximately 50%.

Dose estimates have generally been derived in one of three ways:

- Individual dosimetry: the liquidator was given a personal dosimeter;
- Group dosimetry: an individual dosimeter was assigned to one member of a group of liquidators;
- From itineraries: measurements of gamma radiation levels were made at various points where liquidators worked, and an individual's dose was estimated as a function of the points where he or she worked and the time spent in these places.

It is thought that the level of dosimetric control and the adequacy of dose estimates may vary between civilian liquidators (construction workers, logistic support), military liquidators (soldiers and officers who worked in decontamination, dosimetric control, evaçuation) and radiation specialists.

TABLE II. DISTRIBUTION OF REGISTERED DOSES AMONG LIQUIDATORS IN THE CHERNOBYL REGISTRIES OF THE THREE MOST AFFECTED STATES

Country	Number of liquidators	Dose (mGy)				
		Percentage of doses known	Mean	Median	75% percentile	95% percentile
Belarus						
1986–1989	63 000	13.8%	43.0	23.5	67.3	119
1986–1987, 30 km zone	31 000	28.4%	39.1	20	67	111
Ukraine						
1986–1987	102 000	N.A.[a]	N.A.	N.A.	N.A.	N.A.
Sample studied	*15 700*	*51.9%*	*163.4*	*134.3*	*N.A.*	*N.A.*
Russia						
1986–1989	148 000	63.2%	106.6	92	180.3	240
1986	69 000	50.8%	168.7	194	220	250
1987	53 000	70.5%	91.6	92	100	208
1988	20 500	82.5%	34.0	26	45	94
1989	6 000	73.0%	31.6	29.5	48	52

[a] Not available.

The distribution of recorded doses among liquidators included in the State Chernobyl Registries of Belarus, Russia and Ukraine is shown in Table II. It is noted that doses are missing in these registries for a substantial proportion of the liquidators, particularly in Belarus. Liquidators who worked in the first year generally had higher recorded doses than those who worked in subsequent years. Throughout this paper, efforts are made, where possible, to restrict the presentation to those liquidators who worked in the 30 km zone in 1986–1987, since they are most likely to have actually participated in the cleanup activities.

2.3.2. *Evacuees*

The evacuees are the former residents of the 30 km zone. There were approximately 135 000 persons evacuated, including the 49 000 residents of the town of Pripyat. The evacuation of Pripyat and other locations close to the plant was completed within approximately 40 hours of the accident. Approximately 40 000 additional residents of the 30 km zone were evacuated on 3–5 May 1986 and the evacuation of the 30 km zone was completed during the period 5–14 May [32].

Most of the dose was received in a short time period and resulted from external exposure from the passing cloud and from radionuclides deposited on the ground or other surfaces. Initial reports by Soviet scientists [30] stated that this population had received a collective effective dose from external exposure of 16 000 man·Sv. More recently the doses from external exposures have been re-evaluated by Likhtarev et al. [32]. This re-evaluation was based upon dose rate data from many locations within the 30 km zone and the results of a survey of 42 416 evacuated residents. Individual doses were reconstructed for 13 383 inhabitants of Pripyat and 17 203 residents of other settlements. The average dose to the residents of Pripyat was 11.5 mSv and that of residents of the other evacuated locations was 18.2 mSv. The calculated individual doses vary widely; the maximum value was stated to be 383 mSv. The collective effective dose from external exposure for the entire evacuated population is estimated to be 1600 man·Sv. The collective effective dose from other exposure pathways is not believed to add substantially to the indicated total.

2.3.3. *Human exposure in 'contaminated' areas*

Currently, there are approximately 7 million people who reside permanently in areas with an activity density due to deposited ^{137}Cs of more than 37 kBq/m^2 in areas of Belarus, Ukraine and Russia. The total area covered is about 131 000 km^2 [29]. Doses to these persons resulted both from external exposures from the passing cloud and from radionuclides deposited on the ground or other surfaces and from internal exposures: inhalation of material from the passing cloud in the first days and ingestion of various radionuclides that contaminate foods.

TABLE III. DISTRIBUTION OF THE POPULATION LIVING IN TERRITORIES WITH A ^{137}Cs ACTIVITY DENSITY ABOVE 555 kBq/m^2 IN 1986 [27]

Country	Size of population in 1986
Belarus	~106 000
Russia	~111 800
Ukraine	~52 000
Total	~270 000

Residents of 'strict control zones'

About 270 000 people lived in the 10 300 km^2 of the SCZs, with a ^{137}Cs deposition activity density of more than 555 kBq/m^2 in 1986 (Table III). The collective doses to these populations have not recently been estimated explicitly. However, the dynamics of dose formation have been considered and reported in detail by Balonov and collaborators [29]. From this work, it can be estimated that the average external and internal dose during the period 1986 to 1995 for the population in these areas is approximately 50 mSv per kBq/m^2 of ^{137}Cs deposition density. For the SCZs, a reasonable estimate of the average deposition density is 25 Ci/km^2 (925 kBq/m^2); areas with deposition density greater than 40 Ci/km^2 (1480 kBq/m^2) were generally evacuated. Thus, an approximate value of the average effective dose is 50–60 mSv and the collective effective dose for the 270 000 residents is 10 000–20 000 man·Sv.

Residents of other 'contaminated' territories

An estimate of the collective dose for the remaining 6.8 million persons living in 'contaminated' areas can be made in a similar fashion. The average deposition density is assumed to be 111 kBq/m^2. The average external and internal dose during the period 1986–1995 for the population in these areas is approximately 50–150 mSv per kBq/m^2 of ^{137}Cs deposition activity density (higher than in the SCZs, as there were less strict controls on internal dose). The average effective dose is therefore calculated to be in the range 6–20 mSv. The estimate of collective effective dose is 35 000–100 000 man·Sv. This estimate is compatible with the more rigorously evaluated value of 22 000 man·Sv by Kenigsberg and Minenko [31] for the entire population of Belarus. Their estimate for the average dose to the residents of the Gomel and Mogilev oblasts is 5.9 mSv. A comparable estimate of collective dose for the entire population of Ukraine is given by Likhtarev and Kogan [33] as 47 500 man·Sv, with about 15 000 man·Sv calculated to be delivered to inhabitants of areas with a ^{137}Cs deposition activity density of less than 37 kBq/m^2.

It should be noted that, given the large number of persons residing in these areas, small errors in dose estimates may lead to large errors in the collective dose. Thus, the predicted health effects discussed in the following for this population are very uncertain and should be treated with circumspection. Doses received early after the accident are not known clearly and, as discussed in Background Paper 5, there has been a general tendency to overestimate doses out of caution for radiation protection purposes.

Thyroid doses to populations in 'contaminated' regions

An early exposure situation of special interest, because of reports of major increases in the incidence of childhood thyroid cancer in the more heavily contaminated regions [34–38], is the thyroid dose to the general population living in the heavily contaminated regions of Belarus, Russia and Ukraine. As discussed in more detail in Background Paper 2 on thyroid effects, there is now very strong circumstantial evidence that this increase is related to the dose received from iodine isotopes early after the accident and is not related to any present exposure. Major efforts have been made, and are continuing, to reconstruct thyroid doses to the populations at risk. A summary of the results reported is provided in Background Paper 2.

3. DISCUSSION

3.1. Expected health consequences

This section presents predicted health effects, particularly cancer and hereditary disorders, derived from models of radiation induced risk developed from epidemiological studies of other populations exposed to radiation, mainly the survivors of the atomic bombing of Japan (Life Span Study, LSS). Although there are a number of epidemiological studies from which radiation risk data can be obtained, the studies of the survivors of the atomic bombing continue to be the main source of data for risk estimation [1, 26, 39, 40]. The survivors were, however, exposed primarily externally and at high dose rates. Models must be used to extrapolate the effects of such exposures to exposures at the generally lower doses and lower dose rates due to the Chernobyl accident that are of concern for the majority of the populations. The assumptions underlying these models are inevitably subject to uncertainties. Major questions relate to the choice of models for transfer of risk estimates between populations with different background cancer rates, for projection of risk over time and for extrapolation of risks from primarily external high dose and high dose rate exposures to low dose and low dose rate exposures involving both external and internal radiation.

In the predictions presented here, the estimates for the survivors of the atomic bombing were applied directly to the populations exposed as a result of the Chernobyl accident, on the assumption that, for a given radiation dose, the resulting cancer risk is the same, regardless of the pattern and type of exposure. It is noted that, in extrapolating the risk estimates based on high dose and high dose rate exposures to low dose and low dose rate exposures, the International Commission on Radiological Protection (ICRP) has used a reduction factor (the dose and dose rate effectiveness factor (DDREF)) of two [40]. No DDREF was used here.

3.1.1. Solid cancers and leukaemia

Lifetime risk estimates (through an age of 95 years) were computed for solid cancers and leukaemia (excluding chronic lymphocytic leukaemia) for the liquidators and the populations living in 'contaminated' areas of Belarus, Russia and Ukraine. The methods used follow those of the UNSCEAR 1994 Report [1], using estimates of risk derived from studies of survivors of the atomic bombing, and allowing for the modifying effects of age at exposure and sex (for leukaemia). Table IV presents the predictions of lifetime risk (numbers of deaths) from solid cancers and leukaemia. The number of deaths predicted in the first 10 years after the accident are also presented for leukaemia, but not for solid cancers, because in the model a 10 year latency period is assumed between an exposure and the resulting increase in cancer incidence.

For both solid cancers and leukaemia, the predicted proportions of excess deaths among all deaths from these diseases (i.e. the 'attributable fractions') are small. For solid cancers, they range from less than 1% among the populations evacuated from the 30 km zone and the residents of 'contaminated' areas outside the SCZs to about 5% for the liquidators who worked in 1986 and 1987. The lifetime attributable fraction for leukaemia is greater than that for solid cancers in each population, ranging from 2% to 20%. The fraction of excess leukaemia cases is much higher for the first 10 years.

3.1.2. Thyroid cancer in children

The projections of numbers of thyroid cancer cases were made for population groups that were exposed as children, i.e. between the ages of 0 and 14, in the various oblasts of Belarus and in the Bryansk oblast in Russia, for which both dose estimates and population data were available (Table V). Two sets of published data on the incidence of thyroid cancer were used to estimate the background (naturally

TABLE IV. PREDICTIONS OF BACKGROUND AND EXCESS DEATHS FROM SOLID CANCERS AND LEUKAEMIA IN POPULATIONS EXPOSED AS A RESULT OF THE CHERNOBYL ACCIDENT

Population	Population size/ average dose	Cancer type	Period	Background number of cancer deaths		Predicted excess cancer deaths		
				Number	Per cent	Number	Per cent	AF[a] (%)
Liquidators, 1986–1987	200 000	Solid cancers	Lifetime (95 years)	41 500	21	2 000	1	5
	100 mSv	Leukaemia	Lifetime (95 years)	800	0.4	200	0.1	20
			First 10 years	40	0.02	150	0.08	79
Evacuees from 30 km zone	135 000	Solid cancers	Lifetime (95 years)	21 500	16	150	0.1	0.1
	10 mSv	Leukaemia	Lifetime (95 years)	500	0.3	10	0.01	2
			First 10 years	65	0.05	5	0.004	7
Residents of SCZs	270 000	Solid cancers	Lifetime (95 years)	43 500	16	1 500	0.5	3
	50 mSv	Leukaemia	Lifetime (95 years)	1 000	0.3	100	0.04	9
			First 10 years	130	0.05	60	0.02	32
Residents of other 'contaminated' areas	6 800 000	Solid cancers	Lifetime (95 years)	800 000	16	4 600	0.05	0.6
	7 mSv	Leukaemia	Lifetime (95 years)	24 000	0.3	370	0.01	1.5
			First 10 years	3 300	0.05	190	0.003	5.5

[a] AF: attributable fraction = (excess deaths/total deaths from the same cause) × 100.

TABLE V. PREDICTIONS OF BACKGROUND AND EXCESS CASES OF THYROID CANCER AMONG PERSONS EXPOSED TO IODINE ISOTOPES DURING CHILDHOOD (0–14 YEARS) AS A RESULT OF THE CHERNOBYL ACCIDENT: BACKGROUND INCIDENCE RATES: BELARUS AND WHITE POPULATION OF THE USA FROM 1983 TO 1987 [41].

Population	Population size/ average dose	Period	Background incidence	Background number of cancer deaths		Predicted excess cancer deaths			Total expected to 1996
				Number	Per cent	Number	Per cent	AF[a] (%)	
Belarus									
Brest oblast	377 000	Lifetime (95 years)	Belarus	452	0.12	132	0.04	23	
			US white	1300	0.34	380	0.10	23	
	30 mSv	First 10 years	Belarus	6	0.00	<1	0.00	5	6
			US white	18	0.00	1	0.00	5	20
Vitebsk oblast	361 000	Lifetime (95 years)	Belarus	432	0.12	22	0.01	5	
			US white	1250	0.35	50	0.01	4	
	5 mSv	First 10 years	Belarus	5	0.00	<1	0.00	5	5
			US white	18	0.00	1	0.00	5	18
Gomel oblast	403 000	Lifetime (95 years)	Belarus	438	0.11	1495	0.37	77	
			US white	1400	0.35	4300	1.07	75	
	290 mSv	First 10 years	Belarus	6	0.00	5	0.00	45	11
			US white	20	0.00	17	0.00	46	36
Grodno oblast	302 000	Lifetime (95 years)	Belarus	362	0.12	53	0.02	13	
			US white	1050	0.35	150	0.05	13	

	15 mSv	First 10 years	Belarus	4	0.00	<1	0.00	6	4
			US white	15	0.00	1	0.00	6	15
Minsk oblast	399 000	Lifetime (95 years)	Belarus	478	0.12	104	0.03	18	
			US white	1400	0.35	300	0.08	18	
	20 mSv	First 10 years	Belarus	6	0.00	<1	0.00	5	6
			US white	20	0.01	1	0.00	5	20
Mogilev oblast	294 000	Lifetime (95 years)	Belrus	352	0.12	350	0.12	50	
			US white	1000	0.34	1000	0.34	50	
	90 mSv	First 10 years	Belarus	4	0.00	1	0.00	20	5
			US white	14	0.00	4	0.00	22	19
All Belarus oblasts	2 140 000	Lifetime (95 years)	Belarus	2558	0.12	2157	0.10	46	
			US white	7400	0.35	6200	0.29	46	
	80 mSv	First 10 years	Belarus	31	0.00	7	0.00	18	39
			US white	105	0.00	24	0.00	19	128
Russian Federation									
Bryansk oblast	92 000	Lifetime (95 years)	Belarus	110	0.12	42	0.05	28	152
			US white	300	0.33	120	0.13	29	420
	35 mSv	First 10 years	Belarus	1	0.00	<1	0.00	<20	2
			US white	5	0.01	<1	0.00	<20	5

[a] AF: attributable fraction = (excess cases/total cases) × 100.

occuring) incidence of thyroid cancer: the 1983-1987 Belarus incidence data and the 1983-1987 USA White (SEER) cancer incidence data [41]. The US incidence data were used because it was considered likely that the Belarus thyroid rates underestimate the true incidence, especially before the accident when the Registry may not have been as active as afterwards. The risk projections were made both for lifetime and for the first 10 years after the accident; in both cases a 5 year latent period was assumed. The age and sex specific estimates of risk were derived from studies of survivors of the atomic bombing and a constant relative risk model was used.

The predicted lifetime excess number of cases ranges from 0.01% in Vitebsk oblast to about 1% in Gomel oblast using the incidence rates for the USA, while the attributable fraction ranges from 5% to 77%. The total number of cases expected in the oblasts of Belarus for the first 10 years after the accident varies between 39 and 128, depending on the baseline rates used. The total number of cases expected in Gomel oblast in the first 10 years ranges between 11 and 36. Approximately half of these would occur during childhood (under 15).

3.1.3. Hereditary effects

The basic assumption made in estimating hereditary effects was that, in the first generation offspring of a population of 1 000 000 persons, including all ages and both sexes, 30 cases with hereditary disorders will be observed per 480 000 births per 10 mSv to each parent [42]. The hereditary disorders considered here include autosomal dominant, X-linked, recessive, chromosomal and congenital abnormalities. The background (naturally occurring) hereditary disorders were estimated using the 1993 UNSCEAR Report. The projection model used here follows those of the US Nuclear Regulatory Commission Report [42] and provides the *upper limit* of the risk.

The results presented in Table VI show a very low predicted occurrence of radiation induced hereditary effects, ranging from 0% to 0.03% of all live births and from <0.1% to 0.4% of all hereditary disorders among the live births for the exposed population.

3.2. Summary of available results

3.2.1. Cancer

Table VII presents the number of observed and expected cases of solid cancer and leukaemia in 1993–1994 among liquidators who had worked in the 30 km zone around the Chernobyl plant in 1986–1987, and among the populations in the three countries living in oblasts where some areas had ^{137}Cs activity levels above 185 kBq/m^2. The observed numbers of cancer cases were obtained from the National Cancer Registry in Belarus and from the State Chernobyl Registries in

TABLE VI. PREDICTIONS OF BACKGROUND AND EXCESS NUMBERS OF HEREDITARY DISORDERS IN POPULATIONS EXPOSED AS A RESULT OF THE CHERNOBYL ACCIDENT

Population	Population size/ average dose	Total live births	Total background cases with hereditary disorders		Total cases with radiation related hereditary disorders		
			Number	Per cent	Number	Per cent	AF[a] (%)
Liquidators 1986–1987	200 000 100 mSv	250 000	19 000	7.5	80	0.03	0.42
Evacuees from 30 km zone	135 000 10 mSv	65 000	5 000	7.5	5	0.01	0.10
Residents of SCZs	270 000 50 mSv	130 000	10 000	7.5	40	0.03	0.40
Residents of other 'contaminated' areas	6 800 000 7 mSv	3 300 000	250 000	7.5	150	0.00	0.06

[a] AF: attributable fraction = (excess cases/total cases) × 100.

TABLE VII. STANDARDIZED INCIDENCE RATIO (SIR) FOR ALL CANCERS (ICD 9 CODES 140–208) AND FOR LEUKAEMIA (204-208) AMONG MALE LIQUIDATORS WHO WORKED IN THE 30 km ZONE IN 1986–1987 AND AMONG RESIDENTS IN OBLASTS WITH 'CONTAMINATED' AREAS (>185 kBq/m^2), IN COMPARISON WITH THE INCIDENCE FOR THE GENERAL NATIONAL POPULATION: FOR THE PERIOD 1993–1994

All cancers	Observed	Expected	SIR	95% confidence interval
Male liquidators				
All cancers				
Belarus	102	135.6	75	61–91
Russia	449	404.7	111	101–121
Ukraine	399	329	121	109–133
Leukaemia				
Belarus	9	4.5	200	91–380
Russia	9	8.4	108	37–178
Ukraine	28	8	339	213–465
Population in 'contaminated' territories				
All cancers				
Belarus	9 682	9 387	103	101–105
Russia	17 260	16 800	103	101–104
Ukraine	22 063	22 245	99	98–101
Leukaemia				
Belarus	281	302	93	85–105
Russia	340	328	104	93–115
Ukraine	592	562	105	97–114

Russia and Ukraine. No information could be obtained systematically for evacuees and residents of the SCZs. The expected numbers are based on the general national population; in Belarus, they were obtained from the Cancer Registry, while in Russia and Ukraine they are based on data from regional oncological dispensaries summarized annually at the national level. These results are adjusted for age and sex; for liquidators, they are restricted to men, since the majority of exposed liquidators were men.

Liquidators

There was no increase in the incidence of cancers as a whole among liquidators in comparison with that for the general population in Belarus. In Russia, a small but marginally statistically significant increase was noted among liquidators, of the order of 11%. There was no consistent difference in the incidence of specific types of cancer in Belarus or Russia among the liquidators and among the general population.

In Ukraine, a 20% increase in the incidence of all cancers among liquidators was observed, as well as increases in the incidence of several specific cancer types. As discussed in Section 2.2.2, these results must be treated with caution, since the cases have not yet been verified and the increase may reflect the effect of increased surveillance of the liquidators and previous underregistration of cases in a country where no systematic centralized cancer registry existed at the time of the accident [43].

A total of 46 leukaemia cases were reported among the liquidators in the three countries during the two-year period. A non-significant two-fold increase (based on nine observed cases) was observed in Belarus. In Russia, there was no significant difference in leukaemia incidence among liquidators in comparison with the general population. In Ukraine, a significant increase in leukaemia incidence was observed. It is noted that several authors have reported an increase in leukaemia morbidity among subgroups of liquidators [23, 44–45]; these increases, however, are not consistent and must be treated with caution, for the reasons mentioned in the preceding paragraph.

An increase in the incidence of thyroid cancer was noted in all three countries, based on relatively small numbers of cases (28 cases in 1993–1994). Significant radiation doses to the thyroid may have been received from short lived iodine isotopes by the liquidators who worked in the 30 km zone in the first days after the accident. The data, however, have not yet been analysed according to the time of work in the 30 km zone; information about the histology of the tumours and their mode of confirmation is also not yet available. This result must therefore be interpreted with caution, especially since the follow-up of liquidators is much more active than that of the general population in the three States; for thyroid cancer in adults, the depth of screening may greatly influence the observed incidence [46, 47].

Residents of 'contaminated' areas

No increase was observed in the incidence of all cancers in Ukraine. In Russia and Belarus, a marginally statistically significant 3% increase in all cases of cancer mortality was noted, while no increase was observed for leukaemia in any of the three countries. For thyroid cancer, a 1.5- to 2-fold increase was seen in the three countries. Again, because of increased awareness of the consequences of the accident, and because of the more intensive medical follow-up of populations living in more contaminated regions, these findings must be interpreted with caution, and further analyses are needed to confirm or refute the findings.

A number of authors have recently reported increasing trends in cancer morbidity over time in the populations living in 'contaminated' territories [43, 48]. Care must be taken in interpreting these findings, particularly in countries where no centralized cancer registry exists and for cancer types for which increased ascertainment may result in an apparent increase in incidence. Prisyazhniuk and collaborators [43] have analysed trends in cancer morbidity in the 'contaminated' territories of Belarus, Russia and Ukraine. Although they observed increases in the incidence of all cancers and of leukaemia, they noted that this increase was consistent with pre-existing increasing trends in the incidence of these diseases. The increases were, moreover, not related to the levels of exposure in the regions. The predominant difference with pre-accident rates was noted for cancers in the oldest age group considered (65 years and over), which started as early as one year after the accident. This most likely reflected increased ascertainment of diseases in this population. For leukaemia, the increase primarily concerned chronic lymphocytic leukaemia — a subtype not seen to be associated with radiation exposure in other studies.

Background Paper 2 describes the distribution of the number of cases and the incidence of childhood thyroid cancer in the 'contaminated' regions of the three countries since the accident. As indicated in that paper, a dramatic increase has been observed in 'contaminated' territories of Belarus, Ukraine and, more recently and to a more limited extent, in Russia. The circumstantial evidence that this increase is related to iodine isotopes released as a result of the accident is very strong.

3.2.2. General morbidity

A number of authors have considered the general morbidity of liquidators in the affected countries and compared it with that of the general population in these countries (see for example Refs [23, 48, 49]). Apparent increases in the morbidity for a number of broad disease classes (diseases of the endocrine system, diseases of the blood and blood forming organs, mental disorders, diseases of the circulatory and digestive systems) have been reported. It is difficult to interpret these results. These observations may at least partly be explained by a bias introduced by the active follow-up of liquidators and by the impossibility of taking into account the influence of age and sex in the analyses (see Sections 2.2.1 and 2.2.2). On the other hand, they may reflect a real increase in morbidity following the Chernobyl accident. If so, on the basis of existing epidemiological studies of radiation exposed populations, it is unlikely that they are related to the radiation exposure, although they could be related to stress and economic difficulties following the accident (see Background Paper 4).

3.2.3. General mortality

Recent reports indicate an increase in mortality rates (accompanied by a decrease in the average lifespan) in States of the former USSR [50]. These increases, which do not appear to be related to radiation exposure, since the pattern does not differ between regions with different levels of contamination, may again be related to social and economic difficulties (see Background Paper 4). They must, however, be taken into account in interpreting time trends in exposed populations.

3.3. Comparisons with expected effects

3.3.1. Leukaemia

On the basis of the data from other populations exposed to radiation, the major radiological impact expected to date (i.e. within the first 10 years after the Chernobyl accident), if the experience of the survivors of the atomic bombing is applicable, is leukaemia.

As indicated in Table IV, the increase is mainly expected among liquidators; indeed, out of 190 cases of leukaemia expected in the first 10 years among 200 000 liquidators, 150 (79%) would be expected to have been induced by radiation exposure as a result of the accident. Such an increase can be detected epidemiologically. No consistent increase has been reported to date. The results reported in Section 3.2.1 concern only a two-year period, however, and the power to detect such an increase is thus much reduced.

The expected increase in leukaemia incidence in the first 10 years after the accident in the SCZs and in the 'contaminated' areas is much lower than among liquidators: of the order of 1.5-fold and 1.05-fold, respectively. This is consistent with the fact that no increase in leukaemia incidence was observed among residents of 'contaminated' regions in the three countries. Indeed, such increases would be very difficult to detect epidemiologically.

3.3.2. All cancers

If risk models from other studies of populations exposed to ionizing radiation are applicable, no increase in the incidence of all cancers should be detectable to date. The findings of a 10–20% increase among liquidators in Russia and Ukraine and a 3% increase in the populations residing in 'contaminated' regions in Belarus and Russia, particularly in the absence of a consistent increase in leukaemia incidence in these populations, are therefore not consistent with predicted effects.

The increases observed may be real. They may also, however, be an artefact of the above mentioned differences in the follow-up of disease between exposed populations and the general population of the affected countries (see Section 2.2).

3.3.3. *Thyroid cancer*

The number of thyroid cancer cases expected in the first 10 years after the accident among persons exposed to radioiodine during childhood is presented in Table V. It ranges between 39 and 127 for all Belarus oblasts and between 11 and 36 in Gomel oblast. Approximately half of these cases (i.e. up to 70 in all oblasts and up to 20 in Gomel oblast) would be expected to be childhood cancers (children of <15 years).

As discussed in Background Paper 2, the number of childhood thyroid cancer cases observed to 1995 in Belarus, since the accident, is of the order of 350, over 200 of which have occurred among children who resided in Gomel oblast at the time of the accident. The discrepancies between the observed and expected numbers is outstanding, particularly in Gomel oblast, where the number of cases is at least ten times higher than the predictions mentioned earlier.

The evidence that the increase in the incidence of thyroid cancer in children in the affected States is related to radioiodine released in the accident is strong. The discrepancy between the observed and predicted numbers of cases raises a number of questions, however. This may be due to the large uncertainties in the dose estimates; to short lived isotopes; to an exceptional sensitivity of those who were very young at the time of the accident; to iodine deficiency in the affected areas; to a genetic predisposition, possibly related to ethnic background; or to a combination of these factors. This needs to be investigated further, since there is little information from other populations about the effects of exposure to radioiodine in childhood.

4. FUTURE PROSPECTS

If the experience of survivors of the atomic bombing and of other exposed populations is applicable, the total lifetime numbers of excess cancers will be greatest among the liquidators and among the residents of 'contaminated' territories, of the order of 2000 to 2500 in each case. These increases, however, would be difficult to detect epidemiologically against an expected background number of 41 500 and 433 000, respectively.

Predictions based on other exposed populations and preliminary results to date indicate that the significant health effect most likely to be detected at this time and in the future, besides thyroid cancer, is leukaemia among liquidators. Indeed, if careful large scale studies of liquidators are carried out, they not only ought to have sufficient power to detect an increased risk but also may provide important information concerning the effects of exposure protraction and perhaps of radiation type in the relatively low dose range (0–500 mSv).

The extent of the increase in thyroid cancer is very difficult to predict, as the observed incidence in those exposed as children is, particularly in the Gomel area of Belarus, considerably greater than would have been expected on the basis of past studies. Background Paper 2 discusses the predictions in more detail. Uncertainties mainly concern the temporal behaviour of the increase; if the relative increase stays constant over time, a very large increase in the incidence of thyroid carcinoma may be observed in the next century in adults who were exposed as children.

An increase in the incidence of thyroid cancer in adults (liquidators and populations residing in 'contaminated' territories) has also been reported in recent years. At present, however, this increase needs verification, and it is unclear whether it is related to exposure from the Chernobyl accident or to changes in the ascertainment of this disease due to more active follow-up of exposed populations. Predictions of thyroid cancer risk in those exposed as adults are therefore very uncertain.

Because of the absence of established population based registries in the affected countries (and in most countries), it is difficult to monitor trends in hereditary effects. Given the levels predicted, however, it is unlikely that, if data from other studies are applicable, any increase could be detected in the offspring of the exposed populations.

As indicated in Section 2.2.2, a number of factors limit the power of the routine follow-up activities listed earlier to detect the expected effect of radiation exposure due to the Chernobyl accident, even in the three most affected countries. They include, in particular, the generally low level of radiation dose received by the majority of exposed populations and hence, presumably, the low level of risk expected, the difficulties of systematic and complete active follow-up, the lack of precise dosimetry, and the important movements of populations that have taken place since the accident.

Ad hoc analytical epidemiological studies, focusing on specific diseases and populations, may be a more useful approach to investigating the effects of radiation exposure among the exposed populations. Both cohort and case control studies are generally much more powerful than descriptive studies for investigating dose relationships. To be informative, however, studies of the consequences of the Chernobyl accident must fulfil several important criteria: they must cover very large numbers of exposed subjects; the follow-up must be complete and non-selective; and precise and accurate individual dose estimates (or markers of exposure) must be available. In particular, the feasibility and the quality of epidemiological studies largely depend on the existence and the quality of basic population based registers and on the feasibility of linking information on a single individual from different data sources.

Studies of leukaemia and thyroid cancer risk among liquidators are now under way or planned in all three countries. They are designed as cohort studies and in some cases as case control studies (since pilot studies have shown that cohort studies of these populations would require substantial financial and human resources). Given the distribution of known doses among the liquidators, the power of such studies in individual countries is relatively low, however, and it is essential that studies carried out in different affected countries be similar so that the results can ultimately be compared and combined. Dosimetry still poses an important problem, as dose estimates are missing and of uncertain quality for a substantial proportion of the liquidators in the three countries. Efforts are being made to estimate radiation levels from detailed questionnaires of activities conducted in the Chernobyl area. If these conditions are met, studies of liquidators will provide important information concerning the effects of exposure protraction and perhaps of radiation type in the relatively low dose range (0–500 mSv).

Non-specific studies of cancer risk among the general population exposed in the 'contaminated' regions are unlikely to be informative for radiation risk estimation because of the generally lower doses received by the majority of these populations, and the difficulties in estimating these doses and in following these populations. An exception is the study of thyroid cancer risk in populations exposed as children, the incidence of which has been observed to increase dramatically in the first years following the accident. Careful cohort and case control studies are under way and planned in all countries. They may provide important information on the risk of induction of thyroid cancer due to radiation exposure, as well as a unique opportunity to increase our understanding of factors that modify the risk of induction of cancer due to radiation exposure and thus have important consequences for the radiation protection of patients and the general population.

The predictions described here were made using risk models derived from studies of the survivors of the atomic bombing. As discussed earlier, models must be used to extrapolate the effects of such exposures to the generally lower dose and lower dose rate exposures and for the radiation types of concern for the majority of populations exposed as a result of the Chernobyl accident. These models are, inevitably, subject to uncertainties. Indeed, although an increase in the incidence of thyroid cancer in persons exposed as children as a result of the Chernobyl accident was envisaged, the extent of the increase was not foreseen. It is essential therefore that monitoring of the health of the population be continued in order to assess the public health impact of the accident, even if, given the level of the dose received, little detectable increase of cancers due to the Chernobyl accident is expected except in liquidators.

As discussed earlier, although 10 years have passed since the Chernobyl accident, results published to date are difficult to interpret, mainly because of differences in the intensity and method of follow-up between exposed populations and the general population with which they are compared. In order for results of such monitoring in the future to be unambiguous, it is important that they are based on systematic and complete population based registries, in particular registries of mortality and of cancer. Russia and Ukraine currently lack national population based cancer registries. It is therefore important for monitoring that such registries be established (at least in the 'contaminated' regions in Russia) or improved, where appropriate. Such registries will be useful, not only for assessing the public health impact of the Chernobyl accident, but also for other activities in research and in planning and monitoring for public health in these countries.

5. CONCLUSIONS

Ten years after the Chernobyl accident, there is, apart from the dramatic increase in thyroid cancer in those exposed as children, no evidence of a major public health impact to date of radiation exposure as a result of the Chernobyl accident in the three most affected countries. No major increase in the incidence or mortality for all cancers has been observed that could be attributed to the accident. In particular, no major increase has been detected in rates of leukaemia — even among liquidators — one of the major concerns after radiation exposure. This is generally consistent with predictions based on studies of other radiation exposed populations, in particular the survivors of the atomic bombings in Japan.

Increases in thyroid cancer among those exposed as children were observed in the more heavily contaminated regions of Belarus, Ukraine and Russia, at rates much higher than predicted from previous studies. These increases, which are discussed in more detail in Background Paper 2, may reflect either a particular sensitivity of the population, due to host or environmental factors, or underestimation of doses to the thyroid (possibly due to uncertainties in the estimated doses for the period early after the accident), or the high carcinogenic potential of very short lived iodine isotopes. Increases in thyroid cancer are now also reported among liquidators and the general population; these must, however, be verified before they can be attributed to the Chernobyl accident.

There is a tendency automatically to attribute fluctuations and/or increases in cancer rates over time to the Chernobyl accident. It should, however, be noted that increases in the incidence of some neoplasms have been observed in some countries in the last decades, prior to the accident. A general increase in mortality has, moreover, been reported in recent years in many areas of the former USSR which does not appear to be related to radiation levels. This must be taken into account when interpreting the results of studies.

Increases in the frequency of a number of non-specific detrimental health effects other than cancer among exposed populations, particularly among liquidators, have been reported. It is difficult to interpret these findings because exposed populations undergo a much more intensive and active health follow-up than the general population. If real, these increases may be attributable to stress and to anxiety resulting from the accident; they are discussed in Background Paper 4.

Only ten years have passed since the accident, and on the basis of epidemiological studies of other populations, increases in the incidence of cancers other than leukaemia are usually not visible until at least ten years after exposure. It is noted that the exposures of the public as a result of the Chernobyl accident are different (in type and pattern) from those of the survivors of the atomic bombing. Predictions derived from these populations are therefore uncertain and it is essential to continue monitoring the health of the exposed populations through population based disease registries.

Studies of selected populations are also needed in order to study observed or predicted effects; careful studies may in particular provide important information on the effect of exposure rate and exposure type in the low to medium dose range and on factors which may modify radiation effects. As such, they may have important consequences for the radiation protection of patients and for the general population in the event of accidental exposures.

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DISCUSSION ON BACKGROUND PAPER 3

A.E. OKEANOV (Belarus): In Belarus, certain groups of tumours have begun to behave in an unusual manner during the past few years. Unfortunately, our report does not contain data for different tumour forms, merely risk estimates for all malignant tumours as a whole, but the changes which have occurred are attributable to only some tumour groups. For men in the Gomel oblast, the organs particularly affected are the colon, the rectum, the lungs, the urinary bladder, the kidneys and, naturally, the thyroid; for women (among whom there has been a rise not only in the level of morbidity, but also in the rate at which the morbidity level has been rising), they are the colon, the rectum, the lungs and the thyroid.

As regards liquidators, we have carried out a preliminary study on about 30 000 liquidators living in Belarus and checked on every malignant tumour case, using the Cancer Registry and the Chernobyl Registry and looking to see whether all the cases were subsequently confirmed. We found three cancer types in whose incidence there has been a definite increase: cancer of the urinary bladder, thyroid cancer and leukaemia. The findings are only tentative, but I believe we must continue with our investigations and monitor these cancer types closely.

K. BECKER (International Organization for Standardization): After the Chernobyl accident, governments in western Europe spent hundreds of millions of dollars on destroying agricultural produce, farm animals and so forth in order to "save" a few man-sieverts of population exposure. Also, the collective dose concept has been used in "estimating" tens of thousands of additional cancer deaths in the northern hemisphere, which has caused confusion, anxiety and problems with the public acceptance of nuclear power.

I should be interested in hearing views about the extent to which the collective dose concept is useful at low doses (within the natural background fluctuation range). Should we worry about the potential risks (spending substantial resources on reducing them further), when they are too small to detect?

R.H. CLARKE (United Kingdom, Chairperson): I believe that we need to disaggregate collective dose figures, as far too much information is condensed within a single figure for this to be useful in decision-making. When making decisions it is important to look at how the collective dose is distributed in space and in time and at how the levels of individual risk vary and when the individual doses were delivered, and it is quite proper to put less weight on very low doses and on doses expected to be received in the distant future. In other words, I think one should focus on the fewer people receiving higher doses and on the near term rather than the long term.

M.R. QUASTEL (Israel): There are a number of biological dosimetry methods which involve the use of so-called "biological indicators of radiation exposure" — for example, the measurement of unstable and stable chromosome aberrations using classical radiation cytogenetic techniques and by fluorescent in situ hybridization, the evaluation of glycophorin-A in red cells and the measurement of HPRT mutations in lymphocytes.

At the Ben Gurion University, Beersheva, we have found in liquidators who emigrated to Israel significant increases — relative to a control group — in the numbers of mutated red cells lacking the GPA (glycophorin-A) antigen.

There is, of course, uncertainty about the significance of such biological indicators, and the Chernobyl experience may present an opportunity for determining whether abnormal indicator levels are associated with later health effects.

Are there any plans for trying to relate abnormal biological indicator levels to subsequent neoplasia development in the exposed populations?

E. CARDIS (International Association for Research on Cancer (IARC), Scientific Secretary): In collaboration with colleagues at Obninsk, we have tried to correlate levels of stable chromosome aberrations (measured using the fluorescent in situ hybridization method) with the official figures for the radiation doses received by a group of liquidators residing at Obninsk and with the working history of those individuals when they were liquidators (where they worked, what jobs they did, etc.). We did not find any correlation, but I hope that in due course we shall find a correlation using some other biological indicator.

It must be remembered, however, that the vast majority of the people who worked as liquidators in the 30 km zone during 1986–1987 received relatively low radiation doses at different exposure rates, so that it may not be easy to distinguish biological damage due to radiation from biological damage due to other factors.

I. LIKHTAREV (Ukraine): I should like to use this opportunity in order to say something about the prospects of determining individual radiation doses received by liquidators.

There are three methods currently considered to be promising as individual retrospective dosimetry methods: fluorescent in situ hybridization; the analysis of stable chromosome aberrations; electron spin resonance using tooth enamel; and computations based on the liquidators' "itinerary" during the period of exposure.

As regards collective doses, the size of the collective dose is less important than its distribution among various groups and among the populations of various regions. If one does not know that distribution, one should not really use the collective dose.

A.R. OLIVEIRA (Brazil): I should like to ask the authors of the Background Paper whether, in their predictions of cancer risk, they considered the risk of "situational stress" in triggering extra cases of cancer, for it is well known that people undergoing extremely adverse conditions (due, say, to a death in the family) tend to exhibit an impairment of the immunological response.

K. MABUCHI (Japan): The predictions derived from risk estimates were based on follow-up studies of atomic bomb survivors, and only the direct effects of radiation exposure were considered.

L.A. JOVA SED (Cuba): We performed more than 4500 body activity measurements on children from Belarus, the Russian Federation and Ukraine who had been brought to Cuba, and our dose estimates are in good agreement with the results obtained during the International Chernobyl Project and in other studies.

R. TAYLOR (International Atomic Energy Agency): In the Background Paper, the focus was on follow-up studies of atomic bomb attack survivors as the basis for determining long-term effects of radiation exposures. By now, however, there is a large body of data on radiation workers at nuclear power plants which is being used in refining the data from such studies. What use has been made of radiation worker data?

E. CARDIS (IARC): A number of large-scale epidemiological studies of nuclear industry workers have been carried out during the past ten years or so, with the aim of estimating the effects of relatively low radiation doses received over many years. Perhaps the most comprehensive and informative study carried out so far was one which covered nearly 100 000 nuclear industry workers employed at seven facilities in the United States of America, the United Kingdom and Canada. It yielded the most precise risk estimates available to date. Our estimates of risk per unit radiation dose for leukaemia are intermediate between a linear and a linear–quadratic extrapolation from atomic bomb attack survivors, so that they are quite consistent with the present basis for ICRP's recommendations. All confidence intervals are quite wide; they do not include a protective effect of radiation for leukaemia, but they do include a reduction of effects at low doses and also effects up to about two times our current predictions based on atomic bomb attack survivors. Consequently, in order to replace the survivor data as a basis for estimating the effects of low doses we need to collect more information on populations which have received low doses and are followed up closely with good dosimetry. One such population may be the liquidators.

F.A. METTLER (United States of America): Has there been a calculation of the number of cancer cases which would occur if populations were allowed to return to their contaminated settlements?

I. LIKHTAREV (Ukraine): The return of evacuees is to only a minor extent a dosimetric question or a question of criteria for permitting their return. Rather, it is a social and economic question, because, after the populations in question had been evacuated, the entire infrastructure in the abandoned settlements became ruined. Its restoration would be a very difficult and expensive business.

M. OMELYANETS (Ukraine): I should like to raise a number of points.

Firstly, various Conference participants have stated that the forecast of the numbers of thyroid gland tumours in children has been lower than the actual numbers by a factor of at least two. Also, according to the publication DNA News (September/October 1995), the increase which the International Chernobyl Project found in the incidence of thyroid cancer in children exposed during the first phase of the accident was unforeseen. Moreover, the start of the appearance of such tumours occurred much earlier than had been the case with individuals exposed in other incidents (for example, Hiroshima and Nagasaki victims). Thus, the full implications of the Chernobyl accident are still not known completely and the radiation doses received need to be determined more accurately. In addition, the question arises whether the forecast of the numbers of other neoplasm types is not too optimistic.

Secondly, the data on neoplasms in individuals exposed in Hiroshima and Nagasaki point to a significant increase in the incidence of mammary cancer in females who were exposed before sexual maturity. Also, according to data collected by Prof. Pinchera, girls have proved to be more sensitive than boys as regards the consequences of thyroid exposures, and thyroid cancer occurs earlier in girls than in boys. It would be interesting to know whether such differences were taken into account in the making of forecasts and the calculation of risks.

Thirdly, morbidity is on the increase in the contaminated parts of Ukraine; according to official figures, the morbidity level was almost twice as high in 1995 as in 1987. Changes have occurred in the pattern of diseases, and many demographic indicators point to a deterioration. We can demonstrate this using data on trends in mortality among Chernobyl victims in Ukraine.

From Fig. 1 it can be seen that during the period covered, the mortality among the liquidators rose dramatically. The fact that it remained lower than the mortality in the Ukrainian population as a whole was connected with sex and age structure features and with the initial state of health of liquidators. By 1995, however, the mortality among the liquidators had exceeded that among Ukrainians of working age who were similar to them in age. The standardized indicators/figures calculated with allowance for the elimination of age differences are higher for the liquidators, and the data for the liquidators who worked at the Chernobyl NPP in 1986–1987 are even worse. The liquidators have a higher level of mortality due to neoplasms than the control groups.

As can be seen from Fig. 2, starting in 1988 the mortality level in the populations living in contaminated localities is higher than that in the Ukrainian

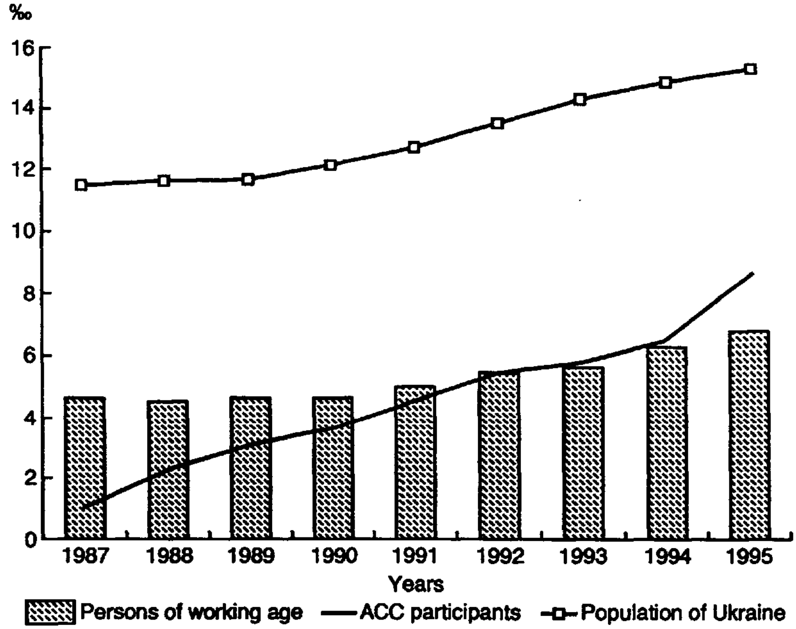

FIG. 1. The comparative dynamics of mortality in 1987-1995 among ACC participants and the population of Ukraine in general, including that of working age (per 1000 persons).

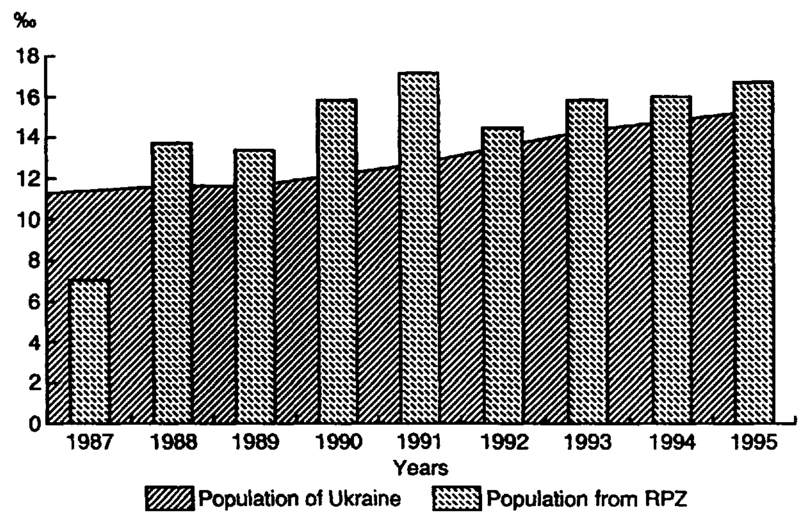

FIG. 2. The comparative dynamics of mortality in 1987-1995 among the population from the radioactive contamination zone and the population of Ukraine in general (per 1000 persons).

population as a whole. In terms of general coefficients the differences are not very significant, but the standardized mortality coefficients are high for exposed individuals.

These data point to the poor state of health of the exposed individuals, which has been exacerbated by the economic crisis in Ukraine and the deterioration in social conditions. According to official figures, during the period 1990–1994 the mean life expectancy of Ukrainian citizens fell by two years, and calculations performed by us point to an even greater decline in the contaminated areas. I believe that, when making forecasts, the experts should bear in mind that poor general health may well increase the impact of low radiation doses.

Lastly, science missed the dramatic increase in the incidence of thyroid cancer, so that it is now necessary to take medical countermeasures in a situation where the morbidity level is rising constantly. The optimistic prognosis of the experts as regards other neoplasms may obscure the thyroid cancer situation, so it might be a good idea to verify the calculations which underlie that optimistic prognosis.

F.A. METTLER (United States of America): With regard to the second of the points just raised, I would say that in the case of most solid tumours the risk derives primarily from caesium, which was measurable in 1990 and still is measurable. The predictions for solid tumours may therefore be quite good.

The International Chernobyl Project predicted almost a doubling of the incidence of thyroid cancer, but given the short half-life of radioiodine the prediction was much more uncertain.

J. JOVANOVICH (Canada): With regard to predictions of future cancer cases, in ICRP No. 60 (paras B56–62) it is stated that "the Commission has decided to recommend that for radiation protection purposes the value of 2 be used for the DDREF (dose and dose rate effectiveness factor), recognizing that the choice is somewhat arbitrary and may be conservative".

The risk factors used by ICRP have been regarded as prudent factors to be used for radiation protection purposes, not as risk factors to be used in predicting the number of people killed in an accident.

However, we often confuse predictions of future deaths with prudent estimates of the upper limits of risk and take the latter as the reality. Then, when we talk to the media, they announce that "one thousand people will die" or "one thousand people have already died". In other words, the result is great confusion.

I should be interested in hearing views about that ICRP recommendation.

R.H. CLARKE (United Kingdom, Chairperson): I believe that no DDREF was used in the prediction calculations presented in the Background Paper. The data relating to Japanese survivors were taken and projected for the population in question, so there was no "protectionism".

J.S. NATHWANI (Canada): Social and economic factors — particularly income levels — play a key role in the general mortality risk which individuals face, those belonging in any society to the lower income groups facing higher mortality risks (and hence having a lower life expectancy) than those belonging to the higher income groups. Were such factors taken into account in the study described by Dr. Cardis?

K. MABUCHI (Japan): No, we did not take such factors into account in making predictions of cancer incidence. I do not think that our predictions would have been greatly affected if we had. There are more important factors which should be taken into account — for example, the uncertainty regarding dose estimates and the accuracy of follow-up data.

M.I. BALONOV (Russian Federation): I should like to make two comments.

The underestimation of the number of thyroid cancer cases after the Chernobyl accident is usually attributed to a lack of knowledge about the risk factor — especially for children. It should be remembered, however, that the iodine-131 release was originally underestimated by a factor of 2–3 and that the calculated collective thyroid dose was also underestimated — by the same factor. Recently, the collective thyroid dose for the populations of interest in Belarus, the Russian Federation and Ukraine was estimated to be in the range 1.1–1.5 million man-grays. We estimate that this corresponds to three to four thousand expected thyroid cancers, 90% of them in children (as in 1986). This is in reasonable agreement with the number of cases currently observed — about a thousand.

The resettlement of people in areas which were highly contaminated in 1986 should perhaps be regarded as a "practice" in the sense of ICRP No. 60, the 1 mSv/year ICRP dose criterion for populations being applied in such cases of resettlement. I believe that, if that were done, the resulting situations would be manageable.

M. FERNEX (Switzerland): Dr. Okeanov, one of the authors of the Background Paper, is monitoring liquidators in Belarus — about 30 000 individuals divided into two groups: those exposed for less than 30 days and those exposed for more. He has described significant differences between the two groups as regards cancer of the colon, cancer of the urinary bladder and leukaemia (see Table I).

Would Dr. Okeanov care to comment?

A.E. OKEANOV (Belarus, Vice-Chairperson): In the Gomel oblast, the most contaminated region, we have noted an increase in morbidity and an increase in the regression coefficient for malignant tumours of the colon, the rectum, the lungs, the mammary gland, the urinary bladder, the kidneys and the thyroid.

TABLE I. NUMBER OF CANCER CASES PER 100 000 INHABITANTS

	Belarus population as a whole	Total liquidators	Liquidators exposed > 30 days	Liquidators exposed < 30 days
Colon	12	18.5	20.1	13.4
Bladder	13	31.1	32.1	27.1
Leukaemia	10.4	23.3	25.8	16.4

Among the liquidators (a cohort of more than 30 000 individuals living in Belarus), the observed incidence of cancer of the urinary bladder, thyroid cancer and leukaemia is in excess of predictions.

It is important to continue monitoring the Belarus population as a whole, as well as these liquidators, and to continue with epidemiological studies.

P. HEDEMANN JENSEN (Denmark): According to the national report "The Chernobyl Catastrophe Consequences in the Republic of Belarus", there is an increased incidence of lung tumours, bone tissue tumours, urinary bladder tumours, kidney tumours and leukaemia in the contaminated areas of Belarus. There appears to be a contradiction in this respect between that report and Background Paper 3.

A.E. OKEANOV (Belarus, Vice-Chairperson): I should like to emphasize that in the Gomel oblast, the most contaminated region, there has been a definite increase in the incidence of cancer of the colon, cancer of the rectum, lung cancer, breast cancer and cancer of the urinary organs.

The authors of the Background Paper presented estimates based on known risk coefficients/factors, but the observed morbidity is in excess of the calculated values. The question which we still have to answer is whether this is due to underestimation of the doses or to a combination of unfavourable factors. There is no contradiction.

TOPICAL SESSION 4

Other Health Related Effects: Psychological Consequences, Stress, Anxiety

Chairperson	B.-M. DROTTZ-SJÖBERG, Sweden
Vice-Chairperson	I. ROLEVICH, Belarus
Scientific Secretary	H. KALTENECKER, UNESCO
Rapporteur	T. LEE, United Kingdom
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ENVIRONMENTAL STRESS REACTIONS FOLLOWING THE CHERNOBYL ACCIDENT*

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Abstract

ENVIRONMENTAL STRESS REACTIONS FOLLOWING THE CHERNOBYL ACCIDENT.

The widespread public anxiety and pessimism about the Chernobyl accident appears to be out of all proportion to the radiation induced health effects. The concept of stress is invoked to explain the widespread damage to general health and well-being. Stress can be defined as the process by which adverse mental experiences have negative effects on bodily functions. The mechanism is physiological, mediated through the autonomic nervous system and the endocrinological system. The International Chernobyl Project study was conducted by the International Advisory Committee in 1990 and published by the IAEA in 1991. The study found significant differences between 'contaminated' and 'clean' areas for symptoms attributable to stress; 45% (30% in 'clean' areas) of the people believed that they had an illness due to radiation exposure. The level of general health was found to be low and almost all ailments were attributed by the population to radiation. These effects (confirmed by other studies) were compounded by poor public understanding of radiation; initial secrecy; subsequent lack of effective communication; and the collapse of the centralized political and economic systems. Distrust of 'authorities' is widespread. One important study using a regression method has shown that 'economic situation' and 'attitude to the future' are better predictors of stress symptoms than contamination level. A large scale survey has compared stress effects in 'restricted', 'non-restricted' (but geographically close), 'resettlement' and control areas. Positive differences were found between the distant control sites (surveyed for comparative purposes) and other sites, but differences between 'restricted' and 'non-restricted' were small. 'Resettlement' areas were no better and, on some criteria, worse. Many respondents believed that they had received a dangerous dose of radiation and that their personal health had been damaged. Other studies question the effectiveness of resettlement as a countermeasure. Neither women nor the elderly show any net benefit and only in Russia is there an overall reduction in stress. An important study has measured 'locus of control', i.e. the belief that

* This paper is a revised and restructured version of "Social and psychological consequences of the Chernobyl accident: an overview of the first decade", presented at the WHO Conference on Health Consequences of the Chernobyl and Other Radiological Accidents, Geneva, November 1995 [1].

one can control one's own destiny, versus 'fatalism'. This was used to predict the response to food controls, measured directly by dose uptake. As expected, 'fatalism' is associated with higher stress levels and lower compliance with food controls. Other research has shown that social support is crucial to recovery from stress and the United Nations Educational, Scientific and Cultural Organization (UNESCO) has set up community centres to provide trustworthy information, individual and group therapy, and a variety of recreational/cultural activities. A range of other initiatives with similar aims are being developed. The allocation of the prototypical public reaction to a correct diagnostic category is an obvious first step in planning future countermeasures. False labelling such as 'vegetative dystonia' and 'radiophobia' is counterproductive. The same applies to the well established category of Post-Traumatic Stress Disorder, although this fits those exposed to the initial event. The alternative suggested is Chronic Environmental Stress Disorder. The original stressor cannot be removed, but it is possible to change the way in which it is perceived and to enhance people's feelings of control over it. This means that beliefs and attitudes have to be changed. The problem is more one of communication than of medication.

1. THE ISSUES

The purpose of this paper is to review the nature and extent of damage to the psychosocial well-being of the populations exposed to the Chernobyl accident; to diagnose the public's reaction by placing it in context with similar events in the past; and to consider the effects of three main countermeasures. These are: food controls, resettlement and community action.

A severe obstacle to the clarification of these issues lies in the difficulty of defining the 'contaminated' or 'affected' areas. These extend well beyond the territories officially designated as contaminated. This is because people are aware of the great irregularity in the pattern of deposition; of the arbitrary nature of the threshold values; of the fact that averages are computed from fairly sparse measurements; and that areas identified by different authorities do not precisely coincide. In any case, they deeply distrust the authorities, are convinced that they have reason to underplay the seriousness of the situation and, indeed, believe that there was a 'cover up' during the early days.

Hence, people in many areas with essentially no radioactive contamination due to the accident are nonetheless affected, albeit to a lesser extent, by the fear of it [1, 2].

Another major group exposed to the accident — variously estimated at up to 800 000 in number — is the 'liquidators' (emergency or recovery workers) (see Background Paper 3 for a discussion). It is unfortunately outside the scope of this paper to review the World Health Organization's (WHO) Chernobyl Accident Recovery Workers Project [3], which is part of its International Programme on the Health Effects of the Chernobyl Accident (IPHECA), but see Refs [4, 5] for details.

The direct physical health effects on those living in 'contaminated' areas are naturally disturbing when considered in absolute terms, but even the direct effects (i.e. thyroid cancers, which are mainly non-fatal), when seen relative to the overall health statistics of the three countries, can hardly justify the extremely high levels of public pessimism and anxiety. According to the Organisation for Economic Co-operation and Development (OECD) [6], "There has been no increase in leukaemia, congenital abnormalities, adverse pregnancy outcomes or any other radiation induced disease". The physical effects certainly pale into insignificance when compared, for example, with deaths from lung cancer arising from radon gas or diseases and deaths from industrial pollution.

It is 100 years since the discovery of the phenomenon of radioactivity (and, a few years later, of subatomic particles), and the consequent revolution in physics, chemistry and medicine has excited enormous and still growing scientific attention. Understandably, most of the interest in the Chernobyl accident on the part of the world community of scientists has been concentrated on radiation measurements, protection and therapy; whereas the main human legacy of the accident has been *anxiety about health* and a *social disruption* that has manifested in widespread health disorders not induced by radiation. These are attributable to the mechanisms now generally accepted by medical science as stress: the negative interaction of mental with bodily processes.

As for these secondary but widespread effects, it is known that stress can be alleviated in a number of ways. An obvious one is to *remove* the stressor, a second is to provide people with a sense of *control* over the stressor and, related to this, a third is to change the ways in which the source of stress is *perceived*.

These are huge tasks. In the present case, the original stressor cannot be removed and uncertainty over its effects, i.e. the effects of the release of radioactive materials on physical health, will remain for a generation at least. Medicine may mitigate these effects by screening, diagnosis and treatment, but it will not remove them; they have happened.

The second alternative is to increase people's sense of control. As already mentioned, three specific countermeasures offering this potential are briefly reviewed in this Background Paper. They are voluntary food controls, resettlement and community action. (Medical procedures to counter any direct health effects of radiation will also increase the sense of control, but their discussion is left to other delegates.)

Thirdly, the most obvious means of providing perceived control over a stressor is by diffusion of knowledge that changes the way in which it is perceived. This issue is also discussed.

One final issue to be considered is that of diagnosis. It should be helpful to compare the pattern of public reaction to the Chernobyl accident with those to similar stressful events in the past. If there are consistencies, this should help with prognosis and with the evaluation of alternative countermeasures.

2. SCIENTIFIC BACKGROUND AND DISCUSSION

2.1. Early psychiatric reports

A small number of papers from the Commonwealth of Independent States (CIS) countries, after noting the early cases of acute and chronic radiation sickness, describe the severe stress reactions that mainly concern us here.

In the months following the accident, psychiatrists from the three countries most severely affected carried out clinical examinations of the affected populations [7, 8]. A total sample of 1572 people were studied. It must be emphasized that these were people "living in the immediate vicinity of the plant".

As will be discussed more fully later, the reported reactions of this group are directly comparable with the syndrome now widely recognized as *post traumatic stress disorder* (PTSD) [9].

> "...in the acute period (2–10 days) the main background was made up of anxiety and fear, while in the period of immediate consequences (less than 6 months) — of fear related to asthenia, and in the period of delayed consequences (more than 6 months) — of alarmed tension with more marked asthenia." (Ref. [8], p. 210.)

It should be noted that the CIS psychiatric profession commonly applies the term '*asthenia*' — largely supplanted in the west — to describe symptoms of lassitude, lack of interest and apparent want of vitality.

Psychoses were rare but, in the three periods referred to, only 8%, 11% and 5% respectively had 'no disorders'. 'Acute response to stress' accounted for 75% in both the first two periods but was down to 29% after six months. Conversely, 'neuroses' accounted for 13% in the first two periods but increased to 66% in the third period (see also Ref. [10]).

The symptoms were not attributed by the clinicians to chronic radiation effects but to stress, although they did not completely rule out a physical aetiology, arguing that the effects of continuous low dose radiation "are still not clearly understood".

Rumyantseva and a group of five colleagues from the Serbsky Research Centre of Social and Forensic Psychiatry [11] report on the findings from clinical interviews of more than 6000 people exposed to the accident.

They conclude that the legacy of the accident, for the majority, is the proliferation of stress disorders, psychosomatic symptoms and learned helplessness (similar to 'asthenia'). These lead to irrational (meaning non-effective?) coping strategies such as avoidance, fatalism and passive refusal of protective measures. A number of other authors, in papers published in professional journals in the CIS countries, arrived at similar conclusions [12–15].

The symptoms were not attributed by the clinicians to chronic radiation effects but to stress, although they did not completely rule out a physical aetiology, arguing

that "the effects of continuous low dose radiation ... are still not clearly understood". (The latest authoritative view on this issue is that there is no 'threshold effect' and it is therefore appropriate to aggregate even the smallest doses into a 'collective dose' [16]. However, if the result is still within the normal background range, we would contend that it presents an ethical as distinct from a medical problem.)

The first organized international effort to assess these social and psychological effects was made by WHO. A working group of experts made extensive enquiries of officials, health care workers and ordinary people in an area with a contamination level of 5–15 Ci/km^2 (185–555 kBq/m^2) [17]. While acknowledging the potential for damage to health by radiation, they were particularly disturbed by the extent of anxiety and fear and by the widespread social disruption caused by the exodus from the area.

2.2. The International Chernobyl Project (1990)

The International Chernobyl Project (ICP) in 1990 [18] was a major scientific collaboration co-ordinated by the International Atomic Energy Agency. It involved over 200 scientists from 25 countries and several international and intergovernmental organizations, including WHO (the author was a member of the International Advisory Committee for the Project).

The assessment focused on the approximately 25 000 km^2 in Belarus, the Russian Federation and Ukraine that were officially reported at that time to have a caesium surface contamination level in excess of 185 kBq/m^2. The assessment did not include the prohibited zone (30 km in radius) around the Chernobyl plant or the people who had been moved from the area or the 'liquidators' (recovery workers). It addressed the radiological consequences for 825 000 people living in 2225 settlements. Measurement samples were based on 35 settlements.

The main emphases were on environmental contamination, radiation exposure and physical health effects of the population living in the 'affected' areas and these results have been fully discussed in the Technical Report [18] and elsewhere. The extensive work on contamination levels by Soviet scientists was largely confirmed, but was judged to include a consistent overestimation for reasons of caution.

The study was conducted before the more serious radiation induced physical effects had manifested (i.e. an increase in thyroid cancers) and although these were predicted in the Report, charges of unwarranted optimism have been levelled at the International Chernobyl Project and the IAEA, and even of *bias* on the part of the many independent scientists involved [19]. The converse is that those seeking foreign aid or wishing to criticize central authorities had an interest in taking a pessimistic view, in magnifying the consequences.

However, our concern here is with social and psychological consequences, about which there has been no such disagreement. As part of the work of the Health

Task Force, a short questionnaire survey was conducted of psychological stress symptoms, attitudes towards the accident and beliefs about the future (see Ref. [20]). This was analysed for a sample of 500 adults drawn from seven 'contaminated' settlements and six similar but 'clean' control settlements surveyed for comparative purposes. It is important to note that these were geographically close and are equivalent to the 'restricted area' and 'non-restricted area' classification used later by Drottz-Sjöberg et al. [2].

Although the 'contaminated' and control areas are demographically similar and the *physical* health effects could not be shown at the time to differ, *the two populations were significantly different in terms of stress and anxiety*. However, it should also be noted that the absolute levels of stress and anxiety were high *in both populations* and morale was abysmally low.

It is re-emphasized that there were no significant measurable health effects that could be attributed to radiation at that time, although the Report anticipated a later increase in cancer of the thyroid and other cancers. All that we shall be discussing here are the secondary effects arising from the psychological appraisal of the accident and the omnipresent threat of future consequences.

General health complaints

We asked whether people thought they had suffered from a number of illnesses over the past two months. The results are summarized in Table I. They show a number of significant differences between the 'contaminated' and control areas and it was noticeable that the significant ones are all stress related perceptions: fatigue; loss of appetite and chest pains. Nosebleeds fall into the same category but did not quite reach statistical significance. There were two further illnesses among those which are significant, i.e. thyroid/goitre and anaemia; these are probably most closely related to people's *expectations*, i.e. their *perceptions* of the effects of radiation. As already mentioned, there was no corresponding difference in the results of *clinical examinations* between the communities in 'contaminated' and 'clean' areas.

Finally, it was found that neither *headaches* nor *depression*, recognized stress symptoms, appear to be different between the 'contaminated' and control areas. However, the general levels were very high in *both* samples.

In another section of the questionnaire, the largest differences relate to two specific symptoms, i.e. *sleep pattern* ($p = 0.001$) and *alcohol* ($p = 0.007$). People in the 'contaminated' areas were much more likely to answer 'yes' to "Do you sometimes feel so tired that you do not want to get up in the morning?" and also to "Do you drink hard liquor?" (Note that p is the probability that an observed difference could have arisen by chance, as distinct from being 'genuine'; e.g. a level of $p = 0.001$ indicates that only 1 in 1000 differences of this size could arise by chance).

TABLE I. INTERNATIONAL CHERNOBYL PROJECT STUDY: PERCENTAGE OF RESPONDENTS WHO REPLIED 'YES' TO POSSIBLE SYMPTOMS[a]

	'Contaminated' settlements	Control settlements	All settlements	Probability (p)
Illness perception regarded as significant ($p < 0.05$)				
Fatigue	89	81	85	0.005
Loss of appetite	53	42	48	0.025
Chest pains	53	43	49	0.026
Thyroid/goitre	25	11	18	0.000
Anaemia	8	5	7	0.035
Illness perception regarded as non-significant				
Headache	81	77	79	0.225
Depression	42	42	42	0.865
Sore throat	40	35	39	0.661
Hair loss	26	25	25	0.707
Diarrhoea or constipation	27	25	26	0.709
Weight gain	19	14	17	0.083
Weight loss	15	15	15	0.934
Menstrual irregularity	9	6	8	0.093
Nosebleeds	16	11	13	0.084

[a] Based on the International Chernobyl Project [18].

There were physical examinations of 501 adults who complained of various symptoms. While many disorders were confirmed, there were no significant differences between the communities of 'contaminated' areas and control areas for disorders of skin; joints; ears, eyes, nose; pulses; neurological disorders; heart; lungs; kidney; ***but there was a difference for disturbances of the abdomen, the organ that is probably most vulnerable to stress effects*** ($p < 0.05$) (Ref. [18], p. 344).

Many of the previous data can be expressed in summary form in the answer to the question "I believe I have an illness due to radiation". Here the difference between the control area and 'contaminated' areas was highly significant ($p < 0.0001$). But notwithstanding this, 30% in the control area answered positively compared with 45% in the 'contaminated' areas. As mentioned earlier, these effects in allegedly 'clean' areas are a recurrent theme.

Several questions were asked about how people perceived their current situation. The future looked bleak for most. Only 10% thought that radiation levels were subsiding and only 15% thought the problems would be mostly solved after ten years; that is, by 1996. In the 'contaminated' areas, 72% wanted to move and 83% of the total sample considered that the government should relocate everyone living there.

Every ailment was attributed to the Chernobyl accident. People believed themselves and their children to be suffering from conditions caused by radiation. They reported in evidence for this a wide variety of symptoms that are known to be associated with stress, but not with radiation.

2.3. A Finnish study

Myllkangas et al. [21], a group of nine colleagues from Finland, arrive at similar conclusions. Their study has the particular virtues that the sample comprised *all* the residents (over 14 years) of a 'contaminated' village (Mirnyi, in the Bryansk region) and a control group of similar size from a 'clean' village (Krasnyi Rog).

Mental stress was measured using the General Health Questionnaire [22, 23] which uses four scales measuring (i) somatic symptoms; (ii) anxiety; (iii) social dysfunction; and (iv) severe depression. In addition, 'perceived symptoms' were recorded using a check list; a total of 17 were elicited. The results appear to be similar to those found in the International Chernobyl Project [18] study. That is, the 'psychological' scores differ between the villages, reflecting anxiety, depression and other indicators of stress, but the prevalence of specific symptoms of physical illness was the same.

Of particular interest is the use of regression analysis to explain the variation in GHQ (general and mental health) scores. The factors of *economic situation* and *attitude towards the future* were better predictors than *contamination level*, which was followed by *gender*. In predicting the 'perceived symptoms', *economic situation* was followed by gender and then by *level of education. Contamination level* did not contribute to the prediction.

2.4. The Kiev study

It has already been emphasized that public concern in the aftermath of the accident extends well beyond the 'contaminated' areas. With some colleagues from the University of Surrey, I was involved in a small survey of the residents of Kiev, six years after the accident [24].

Kiev is 90 km south of the site and, given the direction of the prevailing wind, it avoided any significant contamination. However, as the capital of Ukraine and the nearest large city to the Chernobyl plant, the political and social impact was considerable. Public concern was high and remains so.

TABLE II. IN WHAT WAY DID THE CHERNOBYL ACCIDENT HARM YOUR OR YOUR FAMILY'S HEALTH? (KIEV SAMPLE)

	Percentage
Allergies, immunity problems	3
Nervous, psychological (i.e. anxiety, etc.)	3
Lethargy, fatigue, apathy, headaches	5
Respiratory, throat (including thyroid)	7
General ill health (including combinations of the above)	30
Not affected	52

A 24 item questionnaire was administered to a sample of 225 residents. It covered mainly people's attitudes towards the accident, consequential changes in patterns of behaviour and their perceptions of effects on health.

It can be seen from Table II that the proportion of people in the Kiev sample who attribute their ill health to *specific* disorders is less than in the ICP sample. However, given that Kiev is officially designated a 'clean' area, it is disturbing to see that half of the population believe their health has been affected in some way and one third of the people attribute 'general ill health' to the accident.

Turning to the social consequences, only 5% of the people believe that their social lives have not been affected at all and the remainder (with the exception of about a quarter who 'don't know') mentioned general or specific changes in their lifestyle.

All but 4% of the people believe that a similar accident could happen again and 60% believe that Chernobyl harmed their health or that of their family. The strength of the *emotional* component of people's attitudes towards the accident is indicated by the fact that roughly 40% in each case claim to "worry when they think about nuclear energy" and report that their " ... nerves have become worse" since the accident.

2.5. Two pilot studies of the European Commission

Two further studies providing systematic data on the social and psychological climate some years after the accident have been reported by Allen and Marston [25] and Drottz-Sjöberg et al. [26] under the auspices of the European Commission.

The first of these was a small study in Novozybkov, 160 miles (256 km) from Chernobyl in southern Russia. Allen and Marston analysed 37 intensive interviews and, although the results closely mirror those already described, some additional insights are worth attention.

For example, the delayed and incomplete information about the accident was compounded by disbelief that it could affect a community at such a distance. Passivity and resignation and a feeling of hopelessness were endemic and half the population had made no effort to change their dietary or recreational habits to reduce exposure.

Voluntary resettlement has led to homesickness, stress and hostility; host communities had been resentful of the privileges afforded the incomers and fearful of contagion. This poor outcome was predictable from the extensive literature on relocation [27, 28] which shows that 'attachment to place' is very strong, especially in the elderly. When relocation is involuntary, its baleful consequences are even more damaging.

The other European Commission pilot study by Drottz-Sjöberg et al. [26] (also in Novozybkov) used an exhaustive questionnaire, whose results were analysed with great thoroughness. The sample is rather small (N = 161) but nonetheless of a size adequate for interesting quantitative analysis. The results have been reviewed fully in Ref. [1] and they are largely confirmed in the main survey by the same authors described below.

2.6. A large scale survey of 'restricted', 'non-restricted', 'resettlement' and control areas

In an extensive systematic survey reported in Ref. [2], a sample of 3067 is distributed almost equally between the three Republics and then, within each Republic, between '*restricted*' (officially designated as contaminated), '*non-restricted*', *non-contaminated* (but geographically close to 'contaminated' areas), '*resettlement*' and control areas (plus a small subsample (N = 100) from the 30 km zone).

The questionnaire covered, in addition to demographic variables, questions on health habits, accident concerns and worries, a general hazards checklist, perceived risks and benefits from the accident, relevant knowledge and sources of information and, where applicable, questions about the effects of relocation.

It is confirmed that people in the control areas, especially in Belarus and Ukraine, felt they and their families "had been exposed to real risks" from Chernobyl, to a significantly lesser degree than those in the '*restricted*' and '*resettlement*' areas. Nonetheless, they have a mean scale score of 3 on a 5 point scale, indicating 'some extent' of riskiness. Interestingly, those in the 30 km zone rated the risks only marginally higher than those in the 'resettlement' and 'restricted' areas. As mentioned earlier, those in the 'non-restricted' areas (non-contaminated but near to 'restricted' areas) show almost as much concern over the 'real risks' as their neighbours — and significantly more than those in control areas. Benefits were perceived as minimal by all, including those in the 'resettlement' areas, who might have been expected to have considered rehousing (in some cases to *new* houses) as a substantial benefit.

Mistrust in *internal* sources of information is greatest in Ukraine and is generally at a mean scale position representing 'very little trust at all'. Trust in external sources is somewhat higher in all groups, but in none does the mean value reach scale position 2, i.e. 'trust to some extent'. Trust is predictably lowest in the 'restricted' areas and highest in the control areas, but the difference is small.

Only 5–7% assessed their health as 'rather good' or 'very good'; 20% indicated they had an injury or disease due to their work and as many as 60% claimed some other kind of 'diagnosed disease'. However, perceived current *general* health was assessed on a 5 point scale and the mean scores tell a somewhat less gloomy story. For all groups, they are slightly worse than, but nearest to, scale point 3 and the description attached to this midpoint is 'normal'.

Self-rated *personal* health is somewhat worse, as would be expected, in the 'restricted' compared to the 'non-restricted' and control areas, but again the differences are small. The 'resettlement' areas fare worst — with Ukraine particularly poor.

It is very important to note that the use of sedative medication is disturbingly high — 25–50% depending on Republic and exposure group. The use of stimulant drugs is lower, but nonetheless averaging about 10%. However, most noticeably with sedatives but also with stimulants, usage is greatest in the '*resettlement*' areas, followed by the 'restricted' areas and the control areas (where there is little difference) and lowest in the 'non-restricted' areas.

However, one question asked "Do you have a diagnosed disease, officially confirmed as due to the Chernobyl accident?". Only between 2% and 13% answered in the affirmative, again more from the 'restricted' and 'resettlement' areas. It is noticeable that the exclusion of all but *officially confirmed* diseases produces results very different from those mentioned earlier in response to "Do you have an illness due to radiation?".

A problem in assessing the health comparisons with the 'resettlement' areas is that their generally unfavourable results could be due *either* to the baleful effects of relocation *or* to the fact that their real exposure to radiation prior to relocation was greater *or*, more subtly, to the fact that being selected for, or having chosen relocation, confirmed their beliefs and anxiety about high exposure.

Certainly, the 'resettlement' subsamples claimed they had been "exposed to a dangerous dose of radiation", on average at about 30%, whereas (with the exception of the Russian 'restricted' area) other groups had been exposed to substantially lower doses. It is particularly interesting to note the very low percentages (1.8%; 10.0%; 1.8%) in the control areas. If general health and morale are rather low in the control areas, it is not apparently because they have unrealistic beliefs about their radiation exposure. The important point is that the 'restricted' and 'resettlement' subsamples are consistently worse on this scale.

The same trend is evident in response to the question "Has anybody in your family received a dangerous radiation dose?" and to the question "do you have personal knowledge of any other person who has become seriously ill due to the Chernobyl accident", though here there is some inconsistency. In each Republic, the 'resettlement' areas are worst, the 'restricted' areas come next, followed by the 'non-restricted' and the control areas. The exception is in Ukraine, where the 'non-restricted' area is somewhat worse than the control area. A similar pattern is repeated in the *perceived psychological distress* caused by the accident.

Respondents were asked to select, from a list of eleven, the worst consequence of a nuclear accident. The health risk was by far the most serious, nominated by 35–40%. This is followed by the "uncertainty about the future" and then by the contamination. However, it is important to note that, in the 'resettlement' areas, "having to leave home" is the second most serious consequence, except in Ukraine, where it is rated the worst.

Questions were asked about the relative seriousness of four more general sources of worry or concern. The health effects of radiation were again the greatest cause of concern, but there was little to choose between these and the economic effects, followed by the social effects. Health effects due to diet caused least concern.

Once again, the 'resettlement' areas were most concerned, followed by the 'restricted', the 'non-restricted' and the control areas. However, so far as radiation and dietary effects are concerned, differences between 'restricted' and 'non-restricted' areas are virtually non-existent. The largest difference is between the 'resettlement' areas and the control areas.

The overall picture conveyed by this major survey largely confirms the findings of the ICP and other studies, though it takes a major step forward by including comparisons with 'resettlement' and (geographically distant) control areas.

It confirms the low levels of perceived general and personal health. It reveals levels of *perceived* health damage far beyond anything that could be attributed (using dose–response calculation) to radioactive contamination. The explanation appears to lie with fear of radiation damage, with many judging they have 'received a dangerous dose'. To this must be added political disillusionment (including widespread mistrust of authorities), deterioration in economic welfare and general social disruption. These factors would be expected, through the mechanism of psychological stress, to manifest in poor health. Myllkangas et al. [21] confirmed that this is so. The link to specifically stress prone symptoms was demonstrated clearly in the International Chernobyl Project [18].

What the present study confirms most clearly is that the effects extend, though to a lesser extent, into the (proximate) *'non-restricted'* areas, where radiation *cannot* account for them, and that even the (distant) control areas are not wholly immune.

Most important of all, though, is that *stress effects are not apparently mitigated by resettlement.* On several criteria, results from these areas are worse than those from the 'restricted' areas. As predicted from the literature, the disruption to people's lives outweighs any improvement in physical living conditions [1].

2.7. Locus of control and reactions to countermeasures

It will be evident from the results described so far that for the success of relocation and other countermeasures much depends on the attitudes of those involved. These attitudes were included in a quasi-experimental study of 1800 residents carried out by Allen [29] as a part of the research programme of the European Commission.

The principal objective was to compare levels of stress between samples from 'clean' areas, 'contaminated' areas and a resettled population. Stress (the dependent variable) was measured with the General Health Questionnaire (GHQ) (see Section 2.3 above). The 'predictor' factors to be included in the analysis were the three Republics; exposure level of community ('clean', 'contaminated' and relocated); gender (× 2); age (× 5) and score on a scale of 'locus of control', adapted for the purpose [30].

As mentioned earlier, it is now widely accepted that a feeling of being 'in control' of events has a significant effect in mitigating stress. It is usual to distinguish between 'internal' and 'external' control. The latter is similar to fatalism, i.e. a belief that "There is nothing I can do to alter events" [31].

This study once again confirmed, but in a more systematic, quantitative way (using subscales of the GHQ), that in all three communities in all three Republics there are heightened levels of stress many years after the accident.

Stress increased with age and women reported more stress than men. But some of the more interesting results were found in the differential effects of age and sex on *resettlement*. Women, presumably because their lives (particularly in rural areas) are more rooted in the extended family and the community, did not experience any significant reduction in stress following relocation. The same trend was evident, even more strongly, in the elderly. In fact, *for those above 40 there was no apparent relief from stress compared with levels in the 'contaminated' zone*. Even more disturbing, the overall level of stress was reduced by relocation only in the Russian Federation. The author speculates that this may have been due to a more carefully phased approach to the implementation of the policy.

The findings for *locus of control* were also significant. The 'external' orientation, the belief that events are beyond one's personal control, was associated with higher levels of stress.

The most recent research in this area, by Allen and Rumyantseva [32], is an impressive confirmation that the effectiveness of countermeasures partially depends on purely *social psychological* characteristics of individuals such as locus of control — factors which mediate the behavioural response. In this study, the behaviour being investigated is the *self-selection of a diet that reduces radiation dose in accordance with protection advice*.

It was argued from the earlier work that elevated levels of stress do not necessarily lead to a greater effort to mitigate the cause. People need to *believe in the efficacy* of their corrective actions before they will make the necessary effort. This refers basically to 'locus of control' as in the earlier study, but theories in social psychology have added a further variable to the equation, known as *'personal efficacy'*. Allen and Rumyantseva apply the argument by asserting that these factors will influence the behaviour of food selection as a way of 'coping' with contamination. *This predicted outcome can be directly measured as internal dose* ('whole body counts') and this is the dependent variable of their quasi-experimental design. (In fact, internal doses will obviously vary according to the degree of local contamination and the dependent variable was therefore corrected for this by expressing it *relative to the community average dose*.)

The independent or 'predictor' variables in this study are firstly the level of contamination, comparing three settlements: one high in contamination and with food restrictions (Bobovichy), the second low (Katashin) and the third 'clean' (near Moscow). Secondly, a scale measuring self-efficacy was used, called 'Personal Mastery' [33]. The degree of *perceived threat* to which the subjects were exposed was measured through their own estimates of the degree of local contamination, with nine food types being assessed on five point scales. They were also asked to assess their own absorbed dose as low, medium or high. Finally, the subjects' general expectancy about outcomes was measured on a scale of *'fatalism'* [34].

The results show that the people of Bobovichy, although aware that food controls were in operation, pessimistically attributed higher than actual levels of contamination for most of the listed foods and for an overall index. Despite this and the fact that they believed they had already absorbed a dose higher than that in Katashin (which was true on average), they were *no more likely to follow radiation protection advice*.

Among the possible predictors of dose, the mean scores on the Personal Mastery scale were about the same in both communities, but the Fatalism scores differed in the predicted direction. That is, *fatalism* was lowest in the 'clean' area, higher in Katashin and highest in Bobovichy, the most contaminated settlement.

Next, regression equations were used to determine which of the various 'predictor' variables were most closely correlated with absorbed dose level. The biggest contribution was found to be gender, with women having received lower doses, perhaps through eating less or choosing more selectively. (Alternatively, it *could* reflect differences in caesium metabolism [35]. Next comes *fatalism*; if people believed things are determined by fate, they were found to have received higher relative doses. Finally, there was some evidence that age makes a difference. After the effects of fatalism attributable to age are partialled out, older people, doubtless because they have preserved habitual eating patterns, have received higher doses.

Radiation protection specialists are already familiar with differential responding mediated by biological variables such as gender and age. However, the strong evidence from two studies that a purely psychological variable such as locus of control/fatalism partially governs the response to countermeasures is new and important. *It can be summarized by saying that people's attitudes need to be changed if protection is to be improved.* Interestingly, the present author came to a similar conclusion in a study of people's responses to contamination by radon [36, 37].

2.8. The UNESCO Chernobyl programme

Given that the provision of scientific information, education and social support are acknowledged to be among the most effective ways of mitigating stress in a cultural setting, there is obvious scope for the resources of UNESCO to be brought to bear, mainly for the general population in 'affected' areas but also for liquidators in their community setting.

A major project forming part of UNESCO's Chernobyl programme has been the setting up of community centres. These are designed to provide centres of psychological support, particularly group and individual counselling, to local residents, evacuees and liquidators. Other typical activities include children's playgroups, information seminars, cookery and craft classics, sports activities, art therapy and music. Significantly, the centres were named "Centres of Trust" by the early workers themselves. Nine have now been established, three in each of the Republics. The organizational aspects of their work has been outlined earlier (see Ref. [38]) and I will restrict my comments to their social and psychological implications.

The *need* for such a programme has already been justified, but, to summarize, anxiety about health, their own and that of their families; distress over the accident and its aftermath of denial, inefficiency and administrative confusion, all compounded by the wider breakdown in the Soviet system, have resulted in millions of people whose confidence needs to be restored and who need to believe that their own future and that of their community can be rebuilt. Without downplaying the damage that has been done and without implying that their reactions are pathological (e.g. 'radiophobic'), people need to be convinced that the current levels of contamination to which they are exposed are by no means exceptional when compared with natural radiation levels in many other parts of the world; also that the effects can be controlled.

So far as the liquidators are concerned, there is the particular problem, not only of providing psychological help, but of liaising with the medical support services. For the rest, probably the greatest task is to educate. It is necessary and urgent to convince the population in 'contaminated' areas that most of their symptoms cannot be attributed to radiation but to the physiological consequences of stress. Also that their stress may have arisen either from the accident or from 'normal' living under difficult conditions, probably a mixture of both.

Drottz-Sjöberg et al. (Ref. [26], p. 55) put the situation clearly when they emphasize "... the importance of immediate and reliable information ... for gaining or improving public trust and for relieving stress symptoms".

The size of the task has been and continues to be daunting. The nearest western model for the new UNESCO centres was the 'Community Centre', but in the lingering aftermath of the Soviet system this makes little sense — everything belonged to the community and this concept is now alien to many. Also, the concept of 'social worker' was unknown, psychology was exclusively a behaviourist style legacy of Pavlov and psychoanalysis was seen as a bourgeois heresy.

New staff, mainly western style clinical psychologists/psychotherapists/counsellors and social workers had therefore to be recruited and trained. New buildings had to be constructed or old ones adapted.

Apart from attempting to relieve the stress of *individuals*, the formidable *social* task that has to be addressed is to re-establish the sense of mutual understanding and support *between* people on which mental health so crucially depends. Some idea of the scale of this task can be gained from the fact that, in ignorance of the true nature of radiation effects, refugees are known as 'glow worms' and contacts are avoided for fear of contamination. These social divisions are compounded by envy and by feelings of injustice over the perceived capriciousness of financial compensation, concessions and opportunities for relocation. A similar stigmatization was reported after Hiroshima [39] where the victims were seen by others to present a threat to the 'sense of continuity and immortality'. They were 'tainted with death'. At Fernald, a nuclear processing plant that was a cause of contamination in the USA, victims had to suffer jokes about 'glowing in the dark'.

The extensive literature in social psychology known as 'Social Identity Theory' [40] is concerned with the processes by which the members of the 'in group', threatened by competition for their resources and privileges, constantly reconstrue and overemphasize the *differences* between themselves and the 'out group', who are generally perceived as inferior. This justifies prejudice, which in turn cuts off the social contacts, communication and sharing that could bridge the widening divide. The post-Chernobyl social situation is made worse because the 'glow worms' are often scattered and isolated, unable to draw on the mutual social support of an established group to strengthen their own identity. Even the slow, traditional healing process of intermarriage is hindered by the 'in group', lest the resulting children be deformed or mentally handicapped.

Coaxing people into the Centres is a necessary first step. This has been achieved by creating a bright physical environment that contrasts with the drabness of 'official' buildings. But most of all it has been achieved by 'empowering' the members, encouraging them to participate in running their own affairs and by providing the kind of activities they enjoy. The staff are trained to be informal and relaxed, by contrast with the coldness of officialdom.

Individual counselling is obviously restricted to the most needy. What the majority require is *social support* and this can be mediated through a wide variety of activities, for example, magazines, volley ball, art therapy, writers' groups, aerobics and drama.

For obvious reasons, children are seen as an important group to target and this is done through playgroups and a variety of other activities. However, there is further advantage in that parents are brought together through their children. Children are a common cause — a means of overcoming shyness and breaking down barriers.

2.9. Other UNESCO projects

In addition to the Centres of Trust, UNESCO is attempting to ameliorate the social consequences of the accident through a large number and variety of projects within its remit.

Educational projects include foreign language teaching, the training of staff for the Centres of Trust, the provision of school instructional kits and the supply of educational equipment and facilities. One of the most essential needs is for a clear, attractive and readable leaflet about radiation and ways of mitigating the impact of the accident on the community. Progress is being made with such a project and a prototype version has now been prepared and is currently being extensively peer reviewed.

Turning to the science aspects, efforts are being made to establish an international network for ecological research and a laboratory for the study of radioecology. Studies in hydrogeology are also being promoted and a University Chair has been established in environmental science and management.

Probably the most ambitious scheme is the proposed Economic and Social Development Area. It is planned to establish in Russia a wholly new settlement; a small 'new town' on a green field site. This will be populated by evacuees, liquidators and others whose lives have been disrupted by the accident. It will include schools and a community centre. The legal, economic and political implications of such a scheme are enormous when considered domestically — but when they involve international co-ordination between many countries whose support is needed for a collaborative project with a host country with a divergent culture and systems, the challenge seems almost insuperable. However, detailed infrastructure plans have now been prepared and are currently being independently evaluated.

3. FUTURE PROSPECTS

The preceding review of the research evidence strongly indicates that the future prospects for the areas affected by the accident depend as much on the restoration of a stable political, social and economic order as on specific countermeasures, necessary though these are.

The general demoralization of the population goes well beyond the 'contaminated' areas and 'level of contamination' is not the best single predictor of stress (as measured by the General Health Questionnaire: see Section 2.3). It should be borne in mind that the causes of stress are undoubtedly synergistic; the fear and distrust caused by the accident undermines confidence in the social and political institutions and vice versa.

So far as the fears of health effects from radiation are concerned, it can be expected that they will gradually diminish, although their complete removal may take a generation or more.

The future will depend also on the effectiveness with which the countermeasures can be extended and applied. A critical issue here is that, in line with its apparent priorities, the international community may conclude that the most serious consequences (i.e. the direct health effects of radiation) are now known or predictable and that, once the medical services are felt to be adequate to address these problems, attention can be diverted to other serious international problems.

On the contrary, there is clearly a massive and continuing need for re-education and community support to restore the sense of confidence in the future without which the people will be unable to help themselves by, for example, compliance with food controls and other restrictions (see Section 2.7 above) or to help each other through the mechanisms of community.

4. CONCLUSIONS

4.1. Expert consensus

Little disagreement has been evident in the various research studies reported in this paper; they tend to reinforce and supplement each other. There is a general consensus between psychiatrists, psychologists and sociologists that the physical and mental effects of *stress* are the main issue. This consensus extends to the CIS researchers whose work has been quoted here, who have collaborated closely with those from the west, particularly through the Programme of the European Commission.

A mild exception has been some conflict between the broadly psychological interpretation of events and that of a few senior radiation protection specialists from CIS countries, who have dismissed the public reactions as 'radiophobia'. Other problems have arisen because of differences in the ways in which mental illnesses are classified by psychiatrists from different countries. Both these issues are discussed at greater length in Section 4.4.

4.2. Speculation and myths

Outside the scientific community, there appears to have been almost no limit to the speculation and evocation of myths by the media. It has been argued elsewhere that there is a pervasive dread of nuclear energy, which originates from its close association with the atom bomb and nuclear warfare; also, by virtue of some of the general *characteristics of the hazard*, i.e. 'lack of familiarity', 'lack of controllability' and 'no directly perceivable benefit'.

It is now widely accepted that the media does not generate these anxieties, but exploits them because they attract readership. There follows a process of 'social amplification' as the public reacts to dramatic reporting with increased anxiety, which in turn stimulates further media promotion.

Apart from wild and unsubstantiated reports of 'thousands of cancer deaths', the media has specialized in photographs of children suffering from leukaemia, with the distinctive baldness of chemotherapy; also of elderly people still living in the exclusion zone and apparently suffering from terminal illness. Another favourite media image is of the children of Chernobyl enjoying the benefits of summer camp type holidays in countries abroad in order to relieve the symptoms of illness which, it is implied, afflict them. The children selected by photographers are unlikely to be the most robust ones.

4.3. Open questions

In summarizing briefly the prospects for different supposed countermeasures, it should perhaps first be mentioned that there are no dependable research data on the usefulness of financial compensation or 'special concessions'. Anecdotal evidence suggests that the laudable aim of restoring social equity by this means has failed because the inevitably arbitrary allocations have created the opposite effect, i.e. feelings of *inequity* and jealousy.

By depleting the available financial resources for other countermeasures, the problem has been further compounded. The use of the supposed countermeasure of compensation, as with resettlement, has probably exacerbated the situation further by officially signalling to many people that their health is in serious danger when their risk is well within the normal range for radiation due to natural sources.

As mentioned above, resettlement has failed so far to produce significant improvements in the sense of well-being or reductions in anxiety, when compared with 'restricted' areas. It is difficult to be sure of this, because the population may have been exposed to higher perceived or actual doses before their relocation, but it is more likely that any improvement in their lifestyle has been offset by the severe social stresses of resettlement, combined with similar anxiety and uncertainty about the future of their family's health experienced by those who remain behind in 'restricted' areas. This anxiety may be justified, so far as the effects of prior exposure are concerned, but it does not apply to cumulative, lifetime exposure. A vigorous educational campaign addressed to the resettlement population is obviously needed. There is also some evidence, referred to earlier, that the Russian resettlement programme may have been more successful because of its greater retention of existing community links and a more carefully phased timing.

Hence, it is extremely difficult to predict whether the ultimate health improvements achieved by a reduction in *lifetime dose* will be greater than the damage to health from stress induced disorders. We suspect not. The clearest evidence for this comes from research showing significantly increased illness and mortality rates among elderly people subjected to involuntary moves [1].

To resolve this, there is a clear need to monitor the health of a substantial sample of resettled peoples over, say, a five year period to assess the rate at which symptoms of stress subside and genuine rehabilitation occurs. This would provide a basis for extrapolation for comparison with radiation dose–response calculations.

A strong case for community action has been made already in this paper and is re-emphasized here. Again, there is compelling evidence in the literature that social support from family, friends or community relieves stress (e.g. Refs [41–43]).

The best future prospects for this would appear to lie with UNESCO's 'Centres of Trust'. They appear to be tried and tested and the model is adaptable to local needs and circumstances. However, their importance is such that more systematic evidence of their effectiveness in relieving stress would be welcome. Arrangements are being made for peer review of the Centres and it is understood [44] that some relevant survey evidence is currently being analysed.

It is hoped that a combination of local and international funding will enable many more Centres to be established. Every local authority in the 'affected' and 'resettlement' areas should be ensuring that some kind of 'community centre' support is made available.

Food controls must clearly be retained as a routine countermeasure, but they are obviously frustrating to the people and compliance is alarmingly low. If more food is imported into the 'restricted' areas the local agricultural economy will be demoralized. Home grown food must be a social necessity for many families. Hopefully, there will be a process of decontamination and adaptation, with gradual improvement on several fronts. But an absolute necessity is intensive education so that people gain a sense that food controls are one way in which they can help themselves. The same applies to restrictions on recreation.

UNESCO is working towards this and related goals by preparing a booklet, designed to inform the populations of 'contaminated' areas about the facts of the Chernobyl accident and its consequences, the nature of radiation and the measures that can be taken to reduce or remove its effects. The brochure is aimed at information brokers such as journalists, doctors, teachers and local authorities. All interested parties are currently being consulted on its suitability. The challenge, which the radiation protection community has rarely met, is how to communicate with ordinary people without obscuring their understanding with the *unreal abstractions* (as they appear to them) of particle physics — yet still to maintain scientific integrity and peer approval. The draft document is substantial and UNESCO recognizes the need to produce, at a later stage, a much shorter leaflet for the general public. Over a million copies of such a short leaflet need to be distributed.

In order to reduce stress and improve the effectiveness of countermeasures, it is essential to change the population's beliefs and attitudes. The problem is more one of communication than of medication.

4.4. Questions of scientific interest

Can the reactions to Chernobyl be placed in a diagnostic category?

The main challenge for the medical and behavioural sciences is to make an accurate diagnosis of the nature and causes of the public's reactions to the accident. Upon this depends the choice of the most cost effective countermeasures. The use of psychiatric diagnostic categories does not of itself relieve the symptoms and, indeed, it is now widely recognized that false 'labelling' can be damaging. However, if the categorization is 'correct', it enables us, by relating the condition to previous ones, to offer a prognosis and to propose ways of relieving it. Even in the last decade, there have been considerable advances in disaster/emergency research (see, for example, Refs [9, 45]).

Individuals and groups actively construct the meaning of traumatic events [46, 47]. This contributes to the creation of an 'illness schema' [48] which follows the same cognitive principles as the interpretation of all such events in a person's life. The particular schema that is adopted is obviously of overriding importance to those exposed to the trauma of Chernobyl. Psychiatrists and other scientific observers also attempt to impose meaning — using a process of *categorization* that is based on comparison with similar past events and reactions.

The dangers of this process for both victim and observer are that, once labelled, the condition evolves to acquire the characteristics of the prototype. For example, following a major accident in 1976 in Norway's largest paint factory, some of the victims who experienced psychophysiological disturbances (e.g. palpitations, 52%; sweating, 16%; diarrhoea, 14%) wrongly attributed these bodily symptoms of anxiety to the effect of chemical poisoning and they expected treatment with a chemical antidote. Rumours spread rapidly and only prompt and authoritative information prevented extensive false attributions [49, 50].

There is little doubt that the same process has occurred widely as a consequence of Chernobyl — where the false attribution by the victims has been, of course, to radiation as the causative agent for all ills. Some scientific observers from CIS countries (see Ref. [18], p. 348) have categorized the public reaction as 'radiophobia', but we have argued elsewhere [1], as have others (see Ref. [51] for a full discussion), that this is wholly inappropriate. We can also dismiss 'vegetative dystonia' — a vaguely defined disease entity without clear diagnostic criteria that appeared to convince some victims and physicians that the cause of their ills had been 'discovered'.

Only the effective dissemination of information, leading to the adoption of a different, more valid illness schema is likely to change this.

Unfortunately, once a schema has been constructed, it is self-serving and self-perpetuating. New information is both selected and then construed in terms of the existing schema. If necessary, the 'meanings' of new input are interpreted and made to fit. It is only with reluctance and on the strength of 'irrefutable' disconfirming evidence that an existing schema is changed [52, 53].

Stress and post-traumatic stress disorder

For a better model, the evidence presented here strongly indicates that we must turn to the concept of *stress*, the unique nature of the stressor itself, and some contributory factors from the political and social turmoil and the generally fatalistic attitudes of the people.

The concept of stress is not a vague repository to which all ills that cannot be attributed to familiar diseases are consigned. Stress is directly measurable by a variety of *physiological* indices that have reliably been shown to be closely associated (in a dose–response relationship!) *with adverse circumstances and events* [43].

The main agencies are the autonomic nervous system, which becomes dysfunctional under prolonged or intense emotional arousal, and the endocrinological system. Their engagement can be measured through changes at the cardiovascular level, by neural activity through the electroencephalograph; through skin conductance, through the sodium content of saliva and, perhaps most reliably, by chemical assays of the catecholamines of cortisol, epinephrine and norepinephrine. These can be taken from blood or urine samples; in the research studies following the Three Mile Island accident in the USA, it was found, when the 'affected' population was compared with controls, that these biochemical effects had persisted for several years after the accident [42, 54]. There is emerging evidence that the immune system may also be affected by chronic stress [55].

Nonetheless, it is more usual to diagnose and measure stress in a clinical setting from reported symptoms such as anxiety, depression, disturbed sleep patterns, psychosomatic illness, aggression, suicide or attempted suicide, apathy ('learned helplessness'), family discord and, of course, by the recourse to such palliatives as drugs and alcohol.

Post-traumatic stress disorder (PTSD) is the existing formal categorization which, at first sight, most closely appears to fit the Chernobyl case. This category has become widely recognized (see Ref. [9]) and formally classified as an illness by the American Psychiatric Association in its Diagnostic and Statistical Manual of Mental Disorders (DSM-III-R). PTSD is a syndrome that originates from situations where people are closely involved in a specific catastrophe, for example fire, explosion, earthquake or battle situations, which are so far from normal human experience that they provoke an *extreme emotional response*. The effects on the memory of this experience, combined with the secondary reactions mediated through the body systems, vary in severity and duration according to the closeness to the accident and the passage of time. Hence, those who were working at the Chernobyl plant or nearby at the time and who witnessed the fire and explosion, would certainly fit the now classical PTSD pattern (see Section 2.1).

However, away from the plant, most did not directly experience the event, but only received rumours of it from a variety of sources. They found it hard to come to terms with its true meaning until, perhaps, they were subjected to food restrictions or evacuated. Even in the latter case, realization must have dawned slowly because many expected that they would be returning to their homes and a normal diet when the problem had been cleared up. No evidence of the accident would have been received directly via their senses. Radiation cannot be seen, felt or smelled. Insofar as there was *trauma*, it was not caused by direct experience of the event. It must have been the haphazard but growing conviction that things were going very seriously wrong with their lives and the lives of their children. Over the course of many, many months as information leaked out, this realization became more and more sombre but was surrounded by ever increasing uncertainty. The nature of radiation was not understood, the limits of contamination were not clearly defined and constantly changing, the health effects were disputed and the many countermeasures proposed were most unevenly applied.

Ursano et al. [45] have provided a comprehensive list of symptoms which they regard as typical of PTSD. These fall into three groups: firstly, *'re-experiencing'* symptoms, such as intrusive recollections and nightmares; secondly, *'avoidant'* symptoms, such as avoidance of associated thoughts or feelings, inability to recall important aspects; and, thirdly, *'arousal'* symptoms, such as difficulty in concentrating, irritability and hypervigilance. A full listing of 17 such symptoms is quoted in Ref. [1].

Insofar as *intrusive recollections of the accident itself* and *avoidance symptoms* are dominant features of the classic PTSD syndrome, this diagnostic category is clearly inappropriate for the large majority of those exposed to Chernobyl.

The typical chronic Chernobyl reaction includes only relatively few of the other symptoms. The sense of 'learned helplessness' — of apathy and listlessness (asthenia) that is probably the principal characteristic of the post-Chernobyl reaction, is featured as 'diminished interest' and as 'feelings of detachment', but otherwise the overlap is slight.

Given that there have been a number of similar, if much less serious environmental threats or accidents, a new categorization would seem appropriate to resolve this dilemma. Green et al. [56], on the basis of their experience with the Fernald accident, have already recognized the need to identify a category that is similar to but distinguishable from PTSD. They have labelled it 'Informed of Radioactive Contamination Syndrome' (p. 174). However, this would seem unnecessarily restrictive. Accidents involving a continuing awareness of chemical pollution of the soil; contamination of water supplies; seepage from a landfill site; the threat of flooding; radon gas; the discovery that roads had been sprayed with dioxin tar; even the belief that electromagnetic fields due to power lines or substations are damaging to health — all present similar *chronic threats* with *diffuse origins* that may result in stress. Campbell [57] refers to 'ambient stressors'. Several other authors have reported evidence of physical stress effects (e.g. headaches, nausea) and attitudinal changes (e.g. demoralization, upset, perceived threat, declining quality of life and distrust of authorities) associated with toxic waste disposal sites [57–61].

I would propose *Chronic Environmental Stress Disorder* (CESD) as a more useful formulation for the general population affected by the Chernobyl accident. PTSD would then be reserved for those victims who had experienced the initiating, traumatic event.

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DISCUSSION ON BACKGROUND PAPER 4

K. BECKER (International Organization for Standardization): Some phenomena observed in the Chernobyl fallout areas (reduced life expectancy, increased alcoholism, depression, etc.) can also be observed in other parts of the former Soviet Union. Moreover, the media hysteria in large parts of western Europe led to an estimated additional 40 000 abortions among married women during the post-Chernobyl months (see poster paper CN-63/196). I should be interested in hearing comments regarding such long-term psychological effects of the Chernobyl accident.

B.-M.L. DROTTZ-SJÖBERG (Sweden, Chairperson): Studies carried out by us in Belarus, the Russian Federation and Ukraine suggest that one reason for those effects is that specialists in nuclear energy and related fields rarely write in newspapers or appear on television in order to "put the record straight" about Chernobyl.

E. SCHUCHARDT (Germany): As someone who spent six years living with and helping families affected by the Chernobyl accident in Belarus and Ukraine, I should like to welcome the concept of chronic environmental stress disorder proposed at the end of Background Paper 4.

O. BOBYLEVA (Ukraine): I consider chronic environmental stress disorder to be a useful concept, but I should like to warn against ascribing too many complaints to it.

The overall population affected by the Chernobyl accident in Belarus, the Russian Federation and Ukraine constitutes a group of several million people, living under a variety of widely differing radiological conditions. There are still — ten years after the Chernobyl accident — areas where the activity levels in the milk exceed 370–600 Bq/L, and there chronic environmental stress disorder is unlikely to be the only health problem affecting the local people.

R.A. VASILACHE (Romania): On the basis of studies carried out by them, Romanian specialists have stated that in Romania there is no need to fear an increase in the incidence of cancer as a result of the Chernobyl accident; any excess cancers would go unnoticed against the "natural background". However, the media are not interested in such statements — they prefer publicizing the exaggerated predictions of non-specialists. How can one change this attitude of the media?

T.R. LEE (United Kingdom, Rapporteur): I don't think that one can. There are some responsible newspaper and television journalists, but the remainder are interested only in what surprises or shocks. All one can do is try to educate readers and viewers so that they will see through the charlatanry.

J. JOVANOVICH (Canada): I have been dealing with the media since 28 April 1986 and have come to the conclusion that there are three kinds of journalists:

— knowledgeable ones, with whom we specialists have no difficulty;
— conscientious ones who would like to do a good job, but are asked by their superiors to report on things regarding which they lack the necessary expertise; and
— irresponsible ones who are looking for the sensational story and are not interested in being educated.

Unfortunately, there are many irresponsible journalists, and I think the only way to deal with them is to fight back at them and firmly contradict their reports.

S. FERNEX (Switzerland): UNESCO, which believes in telling the truth in order to dispel undue fears about non-existent health risks, has been doing an excellent counselling and group therapy job under its Chernobyl programme. I feel, however, that there is a contradiction when this happens in communities living in heavily contaminated environments. One such community is the population of Slavutich, a town which — in my opinion — should be evacuated. Would anyone care to comment on this issue?

B. LEFEVRE (UNESCO): The level of contamination within the town of Slavutich is low. At the UNESCO centres the policy is to provide the local people with radiation measurement equipment and to let them decide for themselves in the light of their measurements what they want to do.

V. IDELSON (Ukraine): Journalists reporting on Chernobyl-related matters have a tremendous responsibility, and I hope that the journalists attending this Conference will bear that in mind, particularly after the unjustified comment just made about evacuating the population of Slavutich. I wonder what would happen if the media conveyed that comment to the people living in Slavutich, many of whom are working at the Chernobyl NPP.

M. PAVLOVSKY (Ukraine): The psychological state of those who have experienced the Chernobyl syndrome is decisive for their survival. It is therefore necessary to prevent a further deterioration of their psychological state — by putting an end to the inaccurate, excessively emotional and sometimes tendentious reporting on Chernobyl-related issues in the mass media; by gaining people's trust through improvements in the economic situation, and especially through the creation of more jobs; and by adopting an objective approach to the question of closing down the Chernobyl NPP.

Closure of the Chernobyl NPP would have serious social implications for Slavutich, where the living standards are higher than in any other Ukrainian town and which would be psychologically devastated if the recommendations of the Group of 7 were implemented unconditionally.

M.R. QUASTEL (Israel): We estimate that about 20% of the approximately 650 000 people who have immigrated to Israel from the former Soviet Union came from areas with caesium-137 ground contamination levels higher than 37 MBq/km^2.

At the Ben Gurion University of the Negev, Dr. Julie Cwikel and Mrs. Anna Abdelgani have headed a psychological study of 300 people from such high-contamination areas. The study involved interviews with each of these people and with 300 control subjects matched by age, sex and date of immigration.

The results were significantly consistent with post-traumatic stress disorder among the people from the high-contamination areas. We do not consider this to be a radiation effect, but rather a consequence of their perception and of the disruption of their lives. In addition, there was a significant correlation with blood pressure elevation among the older members of this group (Kordysh et al., Health effects in a casual sample of immigrants to Israel from areas contaminated by the Chernobyl explosion, Environ. Health Perspectives **103** (1995) 935–941).

We agree with Dr. Lee about the need to pay attention to psychosocial effects, which are probably the main health effects at present. It is very important to facilitate communication and to provide trustworthy information, and we have prepared such information for those who are interested.

N. AHERN (European Parliament): In a 1990 IAEA report with which Dr. Mettler was closely associated, it was stated that there was no evidence of disease linked to Chernobyl fallout and that the observed ill health was a result of psychological stress. Even at that time, however, there was evidence — whose existence has been admitted by Dr. Mettler — of abnormal levels of thyroid cancer in children, but it was not published. Children were therefore not screened or treated, perhaps with fatal consequences. How can we be sure that something similar is not happening now?

F.A. METTLER (United States of America): As I said in Updating Session 1, the report referred to by Ms. Ahern (the Technical Report on the International Chernobyl Project) stated that children should be screened for thyroid cancer; it also stated that a significant increase in childhood cancer was to be expected.

Final thyroid cancer data for 1990 were not available at the time of completion of the Technical Report, which mentioned only the thyroid cancer cases which had already been officially reported.

In mid-1991, Ukrainian colleagues sent me information on 21 cases for review. Thyroid cancer was confirmed in these cases at the University of Pennsylvania, and the information was therefore passed on to be used in various international projects currently under way. By that time, however, the Technical Report on the International Chernobyl Project had been published.

The timing of the International Chernobyl Project was unfortunate; better projections of the increase in childhood thyroid cancer would have been possible if the Project had taken place in 1992 or 1993. As Dr. Cardis said earlier today, the actual excess of cases of childhood thyroid cancer is about ten times what she would predict now on the basis of calculated thyroid doses.

Th. ABELIN (Switzerland): The discussion has so far centred on stress and subjective health problems among people living in contaminated areas, and I think attention should also be paid to people (e.g. family members and schoolmates) who are in close contact with the more than 500 children and adolescents diagnosed as suffering from Chernobyl-related thyroid cancer. Such people might well also benefit from programmes of psychological support.

T.R. LEE (United Kingdom, Rapporteur): Unfortunately, there was no strong tradition of psychological counselling in the former Soviet Union, but perhaps something could be done through the Centres of Trust.

C. ZUUR (Netherlands): In order to reduce stress after a nuclear event involving a very small risk of an increase in the incidence of cancer, is it better to administer iodine tablets or to do nothing so as to reassure the people affected?

T.R. LEE (United Kingdom, Rapporteur): I think it would be extremely unwise to play about with placebo effects; the disillusionment when they fail to work could be very damaging. Psychological problems should be tackled with psychological methods.

Y. SAYENKO (Ukraine): The Institute of Sociology in Kiev has for many years been monitoring the socio-psychological effects of the Chernobyl accident on various categories of people — liquidators, evacuees and people living in contaminated areas (including the 30 km zone). Its findings have just been issued in a 30 page monograph which should be available in English also before the end of this year.

The Institute has obtained interesting results, and I think that the relevant international organizations would benefit greatly from co-operating with it.

Socio-psychological rehabilitation will have to take into account the fact that people have undergone three kinds of shock: the first shock was associated with uncertainty due to the information vacuum during the first three years after the accident; the second shock occurred when (in the years 1989–1992) the media told the full story about the accident and its consequences; and the third shock (still being experienced) is associated with the Ukrainian economic crisis, which is now largely overshadowing the direct Chernobyl aftermath and as a result of which there has been a cut-back in efforts to help victims of the accident.

E.V. IVANOV (Russian Federation): Something needs to be done regarding the low level of general knowledge about ionizing radiation — especially among people like teachers, physicians and journalists. One means of educating such people might be a series of readily understandable television films, produced by international organizations for a world audience.

A.M. LUTSKO (Belarus): I think that the time has come to devote more attention to the problem of ignorance about ionizing radiation — a form of ignorance common to all countries.

I do not think that it is necessary to teach journalists radiation safety, and I do not think that radiation safety can be taught to entire populations, but it can — and must — be taught to young professionals.

In that connection, I would mention that in Belarus the A.D. Sakharov International Institute of Radioecology has been doing good work for over four years. The approach at the Institute is an interdisciplinary, analytical one, with problems being tackled from various angles by physicists, mathematicians, biologists, chemists, physicians and specialists in other fields.

V.F. MAZHAROV (Russian Federation): With regard to public ignorance regarding ionizing radiation, I think there is a need for people to receive a "radioecological education" starting in the nursery and continuing through school into adulthood.

In addition, I think there is a need for the establishment of programmes for the preparation of authoritative information about atomic energy by bodies independent of organizations involved in promoting atomic energy. The information prepared by or on behalf of promotional organizations, including the IAEA, tends not to be trusted.

W. PAILE (Finland): It is important to educate basic health personnel such as nurses about what radiation does and does not do, as they are in a key position when it is a question of explaining people's symptoms. For example, a school nurse working in Slavutich who is convinced that when a child complains of headache the cause must be radiation can do great harm to the subjective well-being of the child.

M.T. SUOMELA (Finland): The first slide shown by Dr. Lee when presenting the Background Paper indicated that the mean individual lifetime dose received by the Finnish population from natural radiation was 500 mSv. At present, however, it is estimated that the mean individual annual dose received by the Finnish population from all radiation sources (natural and artificial) is about 4 mSv, approximately three quarters being due to natural radiation. This suggests that the lifetime dose figure is too high.

T.R. LEE (United Kingdom, Rapporteur): Perhaps the Secretariat of the International Atomic Energy Agency should be requested to check the figures.

TOPICAL SESSION 5

Consequences for the Environment

Chairperson	A. BOUVILLE, United States of America
Vice-Chairperson	R. ALEXAKHIN, Russian Federation
Scientific Secretary	M. GUSTAFSSON, IAEA
Rapporteur	M. DREICER, United States of America
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CONSEQUENCES OF THE CHERNOBYL ACCIDENT FOR THE NATURAL AND HUMAN ENVIRONMENTS

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Abstract

CONSEQUENCES OF THE CHERNOBYL ACCIDENT FOR THE NATURAL AND HUMAN ENVIRONMENTS.

In the ten years since the Chernobyl accident, an enormous amount of work has been done to assess the consequences to the natural and human environment. Although it is very difficult to summarize such a large and varied field, some general conclusions can be drawn. The Background Paper includes the main findings concerning the direct impacts of radiation on flora and fauna; the general advances of knowledge in the cycling of radionuclides in natural, seminatural and agricultural environments; some evaluation of countermeasures that were taken; and a summary of the human radiation doses resulting from the environmental contamination. Although open questions still remain, it can be concluded that: (1) At high radiation levels, the natural environment has shown short term impacts, but any significant

long term impacts remain to be seen. (2) Effective countermeasures can be taken to reduce the transfer of contamination from the environment to humans, but these are highly site specific and must be evaluated in terms of practicality as well as population dose reduction. (3) The majority of the doses have already been received by the human population. If agricultural countermeasures are appropriately taken, the main source of future doses will be the gathering of food and recreational activities undertaken in natural and seminatural ecosystems.

1. ISSUES

In order to discuss the environmental consequences of the Chernobyl accident, we must first define 'consequences' and 'environment'. Consequences are the damages that can be observed and specifically attributed to the accident. If the damages do not amount to obvious destruction, there is no unique scientific measure of damage to the environment. In many cases, only changes to the pre-existing conditions can be noted and the designation of damage remains undetermined.

The term *environment* can be broadly defined as the combination of external conditions that affect the development, survival and reproduction of living organisms, and in this respect can be considered to include conditions that affect human beings as well as flora and fauna. One of these external conditions is the natural background of radiation, which was significantly elevated following the Chernobyl accident, especially in the region around the reactor and in the first few months after the accident. Where the additional radiation doses were so high as to affect the survival and reproduction of certain plants and animals, this can be considered a direct environmental consequence of the radiation exposure caused by the accident.

The usual considerations for the human environment are doses and health risks, loss of agricultural production and loss of normal land use. The external conditions were also altered because of the protective actions taken for radiation protection purposes. These actions may have changed the conditions for development and survival of various plants and animals, and their secondary impacts can be considered an indirect environmental consequence.

The main issues to be addressed in this Background Paper are the environmental consequences that can be attributed specifically to radiation due to the release following the accident and the subsequent protective actions taken as a result of the accident, as well as the prognosis for the human environment.

2. BACKGROUND

For decades, research in radioecology and radiation protection has addressed the potential impact of releases of radioactive material to the environment. Except in the few cases for which the effects of previous accidental releases (such as the Kyshtym accident in the USSR and the Windscale accident in the United Kingdom, both in 1957) could be studied, field and laboratory experiments have been conducted in order to assess the doses to humans. These experiments have investigated (1) the direct effects of radiation from large controlled sources on plants and animals, or (2) the movement in the environment of relatively low levels of radionuclides arising from the production and use of nuclear materials (including atmospheric weapons testing and nuclear power production).

Direct effects of radiation on plants and animals

The sensitivity of plants and animals to ionizing radiation varies widely, depending on the species [1, 2]. The significant effects of exposure range from impaired reproductive capacity at high doses to death at very high doses. Other effects include reduced growth and lower yields of plants. It should be noted that these effects can also be caused by environmental factors other than radiation. Because of the complexities involved, generalization is difficult. However, sensitivity to direct effects of radiation exposure may be ordered approximately as follows (from most sensitive to least sensitive): mammals, birds, fish, amphibians, reptiles, crustaceans, molluscs, insects, bacteria, protozoa and viruses. Higher plants overlap the upper range of sensitivity of animals, and mosses, lichens and algae fall in the lower ranges of sensitivity. For all organisms, the earlier life stages are the most sensitive. Thus, the embryo and juvenile stages and in general the active growth and development phases show the greatest sensitivity to radiation.

The response of organisms to radiation exposure may become manifest from the level of the individual cell to the ecosystem level. The significance of any response depends on the criterion adopted for judging damage. For humans, ethical considerations generally presume the individual to be the principal subject for protection. Humans display a wide range of attitudes towards other species, but for the vast majority of organisms it is the populations that are considered important.

High doses of radiation received over short periods are able to induce changes in attributes such as mortality, fertility, growth rate, vigour and mutation rate in individual plants and animals. Lethal dose thresholds for certain radiosensitive plants (such as coniferous trees) are typically about 10 Gy, with severe growth inhibition at some 40%–50% of the lethal dose and failure to seed at perhaps 25% of the lethal dose. At doses less than 10% of the lethal dose, plants typically maintain normal appearance [3]. Mammals are the most radiosensitive terrestrial animals — acute lethal doses are of the order of 6–16 Gy for small mammals and 4–8 Gy for larger animals and domesticated livestock [4]. The reproductive rates of mammals may be depressed at doses that are 10% of lethal doses.

For chronic low levels of radiation, if the dose rate is below about 1 mGy per day, measurable detrimental effects among populations of terrestrial animals and plants are unlikely. For aquatic organisms, even higher dose rates, 10 mGy per day, lead to no significant effect at the population level [5, 6].

Radiation effects at the population and community levels are manifest only if sufficient numbers of individuals are killed or their reproduction is affected. Alterations to genetic information caused by radiation within the cells of an individual organism are, for various reasons, extremely unlikely to be perpetuated at the population level [7]. Other species may be indirectly affected, by loss of habitat, for example, or gain of a competitive advantage. It should be noted that radiation is only one of the sources of stress that can alter the equilibrium between communities and ecosystems, and it is often difficult to attribute an observed response to a specific cause.

The human environment

Most research on radionuclides in the environment has been performed to gain a better understanding of the transfer of radionuclides via plants and animals to human beings (e.g. [8, 9]). Major programmes were in progress before 1986 to develop and improve complex models that evaluate the likely consequences of accidental releases to the environment in terms of human health effects and the areas of land affected by countermeasures (e.g. [10]). Radionuclides such as ^{131}I were shown to be often important in the short term and ones such as ^{137}Cs and ^{90}Sr had been shown to be important in the long term.

The environmental models that had been developed by 1986 were adequate for the purposes of putting into effect guidance on countermeasures in the early phase of an accident to protect against initial high dose rates. Less attention had been given to the possible need for employing complex countermeasures in the longer term. The models focused on the major components of the risk to humans; minor components and transfer in less common environments were less well studied.

Thus, for example, at the time of the Chernobyl accident it was possible to predict fairly accurately the resulting concentrations of radionuclides in milk, cereals, meat and green vegetables and their change with time in the short term, and to incorporate these expectations into emergency plans and take effective actions. However, there were some environments, for so-called natural and seminatural ecosystems (e.g. forests and meadows), for which the existing information was not sufficient or was not adequately synthesized for predicting accurately the behaviour of relevant radionuclides. Moreover, before the accident, it was usual practice to calculate average values of radionuclide concentrations and radiation doses. Since the Chernobyl accident, more attention has been given to evaluation of the variation in radionuclide concentrations and radiation doses.

At the time of the Chernobyl accident, although ranges of intervention levels existed for the most relevant countermeasures (such as sheltering, evacuation, distribution of stable iodine tablets, relocation and food countermeasures), there remained some confusion about their application. In particular, there were misconceptions about the role of dose limits, the need to consider avertable doses in assessing the benefits of a countermeasure, and the need for realism in the application of action levels [11, 12].

Since then there have been major efforts by several international organizations to elucidate these issues, particularly by the International Commission on Radiological Protection (ICRP), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the European Commission, the Food and Agriculture Organization of the United Nations (FAO), the World Health Organization (WHO) and the IAEA (see for example [13–15]).

Another impact on humans in addition to the doses received is the loss of amenity of the environment for the present and future generations owing to increased levels of radiation or contamination above action levels. The loss of commercial use of the land, restrictions or bans on the use of recreational areas and on the consumption of wild or home grown foods affect the local living conditions. In some cases, perceptions of the contamination rather than its actual physical effect can be a significant factor.

Radiation protection is concerned with the protection of the health of individual human beings from the effects of ionizing radiation. Conventionally it has been thought likely that the level of protection required for individual human beings will protect other species in the human environment, although not necessarily all individual members of those species.

3. DISCUSSION

Release and dispersion of radioactive material

In August 1986, Soviet experts reported to the IAEA on their evaluation of the amount of radionuclides released as a result of the Chernobyl accident (the 'source term') [16]. At that time, contours of contamination density had been drawn from the evaluations of amounts of radioactive material deposited and the release estimates were based on the material estimated to have been deposited inside the contours. These contours did not extend outside the USSR. Since that time several studies have been carried out to refine the original estimates and to take into account among other things deposition outside the USSR [17–20]. Revised estimates are presented in Table I and broad agreement exists between them. Notably, the revised estimates of the total release of ^{131}I and ^{137}Cs are approximately twice those of the original June 1986 evaluation.

The releases that occurred at the time of the explosion and during the 10 days that followed can be divided into several stages. The total daily releases (decay corrected to 6 May 1986) as presented in the first report of the International Nuclear

TABLE I. ESTIMATES OF ACTIVITIES OF THE PRINCIPAL RADIONUCLIDES RELEASED IN THE CHERNOBYL ACCIDENT

Element group	Radionuclide	Activity of release (PBq)[a]	Activity of release (PBq)[b]
Inert gases	Kr-85		33
	Xe-133	6500	6500
Volatile elements	Te-129m		240
	Te-132	~1150	1000
	I-131	~1760	1200–1700
	I-133		2500
	Cs-134	~54	44–48
	Cs-136		36
	Cs-137	~85	74–85
Intermediate	Sr-89	~115	81
	Sr-90	~10	8
	Ru-103	>168	170
	Ru-106	>73	30
	Ba-140	240	170
Refractory (including fuel particles)	Zr-95	196	170
	Mo-99	>168	210
	Ce-141	196	200
	Ce-144	~116	140
	Np-239	945	1700
	Pu-238	0.035	0.03
	Pu-239	0.03	0.03
	Pu-240	0.042	0.044
	Pu-241	~6	5.9
	Pu-242		0.00009
	Cm-242	~0.9	0.93
Total (excluding noble gases)		5300	8000[c]

[a] Estimate of total release during the course of the accident [20] based on Ref. [21].

[b] Estimate of release decay corrected back to 26 April 1986 based on Refs [18] and [19].

[c] The total release reported by the USSR [16] was 1.9 EBq (excluding noble gases); decay corrected to 6 May 1986. The estimates here are decay corrected back to 26 April 1986. Thus the present release estimate appears considerably higher, about 8 EBq, because it includes more short lived radionuclides. However, it should be considered a probable overestimate for the total release, since many of these radionuclides would have decayed inside the damaged core before any release to the atmosphere could occur.

Safety Advisory Group (INSAG) are reproduced in Fig. 1 [16]. Some short isolated releases in the 20 days after the accident were inferred from measurements [19], but the interpretation of these data is still debated and in any case they do not significantly affect the general picture.

The pattern of atmospheric dispersion and deposition of the radionuclides was complex owing to large variations in the release fractions of the different radionuclides and changing meteorological conditions. An example of the trajectories of radioactive plumes originating from releases at Chernobyl at six different times is

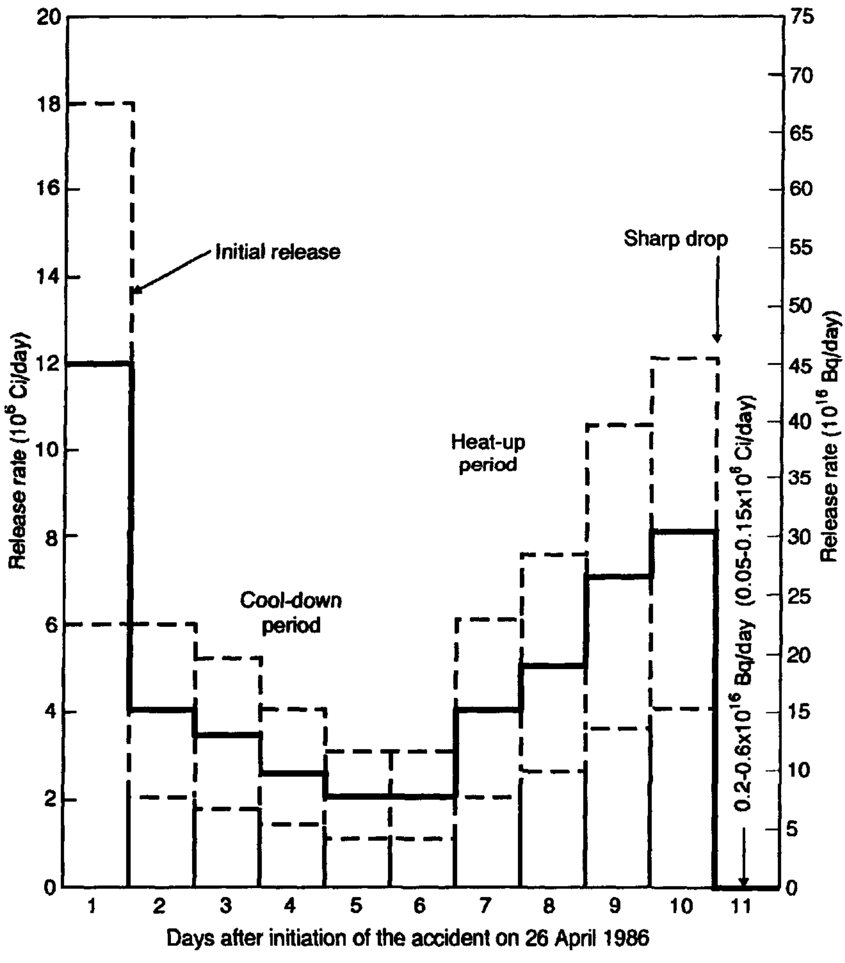

FIG. 1. Daily release of radioactive substances to the atmosphere (not including noble gases) due to the Chernobyl accident; the values shown are calculated from dynamics of the releases from the burning reactor and decay corrected to 6 May 1986 [16].

given in Ref. [22]. Owing to the time course of emissions, the patterns indicated as '1' and '2' are expected to be relatively enriched in ^{131}I compared with ^{137}Cs.

The distribution of fuel particles ('hot' particles) has been estimated as 0.3–0.5% of the core on site, 1.5–2% of the core in the near zone of 0–20 km; 1–1.5% of the core was deposited beyond 20 km [23]. The volatile elements were more widely dispersed beyond 100 km. About 45% of the total ^{137}Cs was deposited within the USSR (predominantly within Belarus, Ukraine and parts of Russia), 39% in Europe, 8% in Asia, 7% in the oceans and the remainder in the other regions of the northern hemisphere [24]. Essentially no material was detected in the southern hemisphere. More sophisticated analyses of the deposition pattern have recently been performed [25] that may lead to a refinement of the UNSCEAR figures and source term estimates.

Approximately 85% of the total release was composed of radionuclides with half-lives shorter than about a month; another 13% was of radionuclides with half-lives of several months; about 1% had half-lives of about 30 a; while about 0.001% had half-lives greater than 50 a. Table II indicates how the total activity of the material remaining in the global environment declines with time. Thus, after ten years of radioactive decay, the activity of all the radioactive material still present in the environment has fallen to about 1% of the total activity of the material released (which was 80×10^{15} Bq for long lived radionuclides, principally ^{137}Cs and ^{90}Sr).

TABLE II. RESIDUAL RADIOACTIVE MATERIAL IN THE GLOBAL ENVIRONMENT DUE TO THE CHERNOBYL ACCIDENT

Significant radionuclide	Released in 1986 (PBq)[a]	Remaining in 1996 (PBq)	Remaining in 2056 (PBq)
I-131	1200–1700	0	0
Sr-90	8	6	1.5
Cs-134	44–48	1.6	0
Cs-137	74–85	68	17
Pu-238	0.03	0.03	0.02
Pu-239	0.03	0.03	0.03
Pu-240	0.044	0.044	0.03
Pu-241	5.9	3.6	0.2
Am-241[b]	0.005	0.08	0.2

[a] Estimate of release decay corrected back to 26 April 1986 based on Refs [18] and [19].

[b] The activity of ^{241}Am in 1996 has increased since 1986 as it is a daughter product of ^{241}Pu (half-life 14 a). This increase has to be considered in any radiological prognosis; however, the doses from ^{241}Am will not exceed the present doses from other radionuclides.

Because of the short half-life of ^{131}I (8 days), adequate measurements could not be made for this radionuclide. Maps of deposition were developed on the basis of dose rate measurements, dispersion calculations and limited information on the radionuclide mixes. These maps cannot be corroborated, which is unfortunate, because one of the more convincing potential radiogenic effects of radioiodine is an increased incidence of childhood thyroid cancer such as that observed in Belarus, Russia and Ukraine.

Caesium-137, an important contributor to human doses, has a longer half-life of 30 a, and efforts have therefore continued to refine the ^{137}Cs deposition density maps (Figs 2–4). The most recent estimates of the area of land contaminated above certain levels in Belarus, Russia and Ukraine are presented in Table III. The deposition of ^{90}Sr and plutonium generally reached significant levels only in close-in areas. The overall patterns of contamination by these long lived radionuclides has remained essentially unchanged over the past ten years, with relatively little secondary transport of material. These environmental levels have been corroborated and will not change even if estimates of the total amount of activity released are revised.

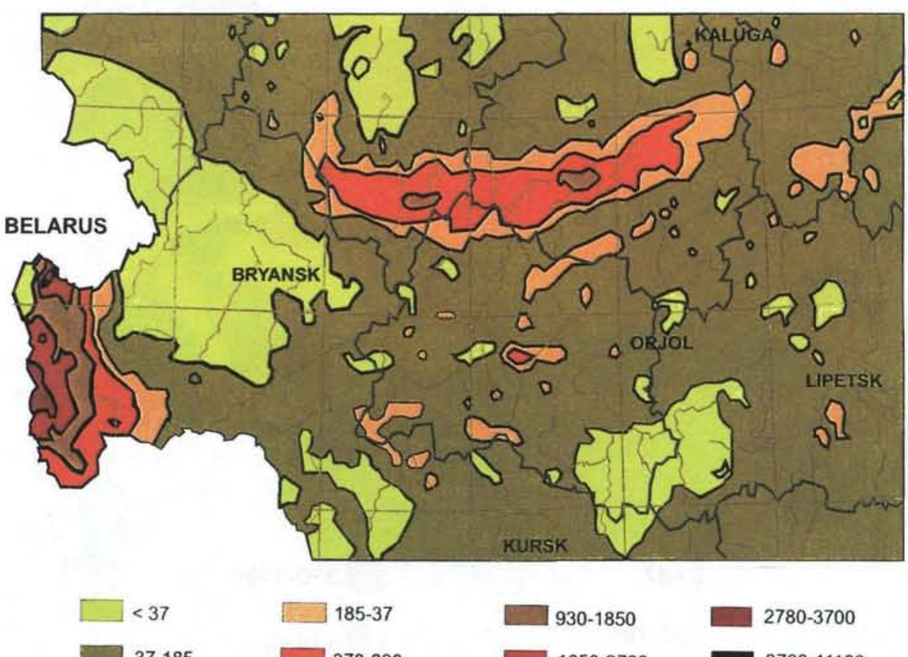

FIG. 2. Map of ^{137}Cs contamination in the western part of the Russian Federation as restored for 10 May 1986 (kBq/m^2).

FIG. 3. Map of ^{137}Cs contamination in Belarus as restored for 1 January 1995 (kBq/m^2).

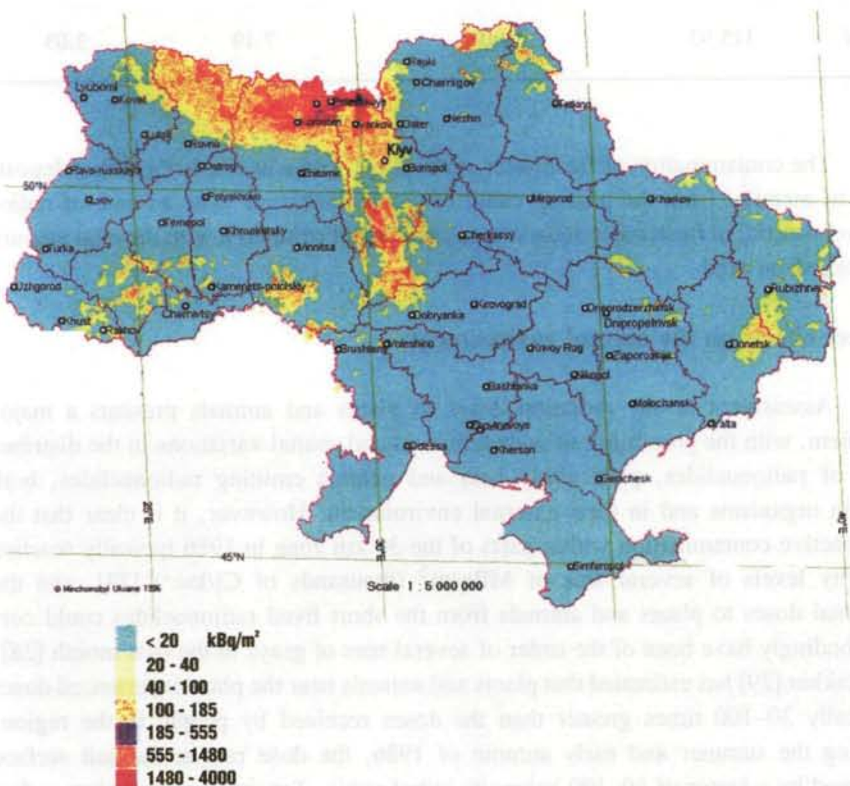

FIG. 4. Map of ^{137}Cs contamination in Ukraine (1996) (kBq/m^2).

TABLE III. AREA OF ^{137}Cs CONTAMINATION OF THE TERRITORIES OF BELARUS, RUSSIA AND UKRAINE (thousand km^2) [26]

Country	Surface deposition			
	1-5 Ci/km^2 37–185 kBq/m^2	5–15 Ci/km^2 185–555 kBq/m^2	15–40 Ci/km^2 555–1480 kBq/m^2	>40 Ci/km^2 >1480 kBq/m^2
	Control zone ($\times$ 000 km^2)	Voluntary evacuation zone ($\times$ 000 km^2)	Obligatory evacuation zones ($\times$ 000 km^2)	
Belarus	29.92	10.17	4.21	2.15
Russia	48.8	5.72	2.1	0.31
Ukraine	37.21	3.18	0.88	0.57
Total	115.93	19.07	7.19	3.03

The contamination of freshwater systems early on was due to the direct deposition of material from the passing cloud of contaminated air. The amount of radioactive material in freshwater aquatic systems is small compared with the total amount deposited on land.

Direct effects on the natural environment

Assessment of the radiation doses to plants and animals presents a major problem, with the possibility of wide temporal and spatial variations in the distribution of radionuclides, particularly beta and gamma emitting radionuclides, both within organisms and in their external environment. However, it is clear that the radioactive contamination within parts of the 30 km zone in 1986 typically reached activity levels of several tens of MBq/m^2 (thousands of Ci/km^2) [27], and the external doses to plants and animals from the short lived radionuclides could correspondingly have been of the order of several tens of grays in the first month [28]. Alexakhin [29] has estimated that plants and animals near the plant experienced doses typically 30–100 times greater than the doses received by people in the region. During the summer and early autumn of 1986, the dose rate at the soil surface dropped by a factor of 10–100 below its initial value. Ten years on, caesium radionuclides are the major contributor to low dose chronic irradiation.

Direct radiation injury of plants and animals was reported only for localized areas within the 30 km zone in the first three years after the accident [26]. Although the chronic dose rates in some of these areas theoretically may be at levels at which the fertility of some animal species might be affected, the average doses to animals are lower owing to their mobility; moreover, any impacts are difficult to distinguish from the effects of confounding factors.

Five years after the accident there were reports that even the most heavily affected zones were showing substantial recovery. The forest stands inside the 10 km zone appear to have been restored to viability [30], soil fauna are recovering and rodent populations are increasing [31]. Life in the area seems to be thriving owing to the decrease in the human population. No evidence has been found that any plant or animal species has been permanently eliminated from the most contaminated areas except where clean-up activities and soil removal have drastically altered the ecosystem [32].

Effects on plants

The accident at Chernobyl happened in the early growing season, the most radiosensitive period for plant communities, when accelerated growth and formation of reproductive organs occurs. As would be expected on the basis of past research, coniferous forests were extremely sensitive to radiation. Within two weeks of the accident, 500–600 hectares of trees in the vicinity of the reactor site received a dose of 80–100 Gy[1], resulting in death of pine trees (so-called 'red forest') and partial destruction of the crowns of birch and alder trees. In the zone nearest to the reactor, small stands of coniferous forest were almost completely destroyed. Over a larger area (approximately 3000 ha) where absorbed doses exceeded 8–10 Gy, 25–40% of coniferous forests died; 90–95% of pine trees showed significant damage to their reproductive tissues. However, by 1988–1989, most of the communities in this zone had recovered their reproductive functions. Those stands of trees that died amounted to less than 0.5 % of the forested area of the zone [26, 33].

Morphological abnormalities in some vegetation, such as distorted and swollen bulges in stems, curled leaves and dwarfism, were reported. The same radiation conditions did not lead to any visible changes in growth or reproductive function of most species of herbaceous plants. Practically none of the species of herbaceous plants investigated revealed any significant relationship between the normal biological indicators and absorbed dose [26]. The production and viability of herbaceous plant seeds appeared relatively normal within three years of the accident, suggesting the ability for plant regeneration [34].

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[1] For comparison, doses of typically 10–1000 Gy are used to artificially induce mutations in seeds for plant breeding purposes.

Effects on animals

Reported effects on animals at high initial doses range from severe direct effects to observable, but not necessarily significant, changes to the general health of populations. Reproductive and genetic disorders have been seen in mice populations. There were observations that populations showed instability and that genetic disorders increased with dose [31, 35]. At the present time, a number of studies carried out under various conditions are beginning to report possible genetic changes. In some cases, the populations returned to normal in a few years. At this time it is not possible to determine the long term significance of the consequences, but some of the results are cited here.

Cows consuming contaminated pasture close to the reactor in the early phase after the accident received high thyroid doses in the range of hundreds of grays, resulting in atrophy and total necrosis of the thyroid [36].

Arthropod populations (mainly insects and spiders) in the 30 km zone showed marked population decreases during 1986–1987 owing to the accumulation of radionuclides in the forest litter and the topsoil layer [37][2]. The current status of these populations is unknown.

There have been reports of a reduction in the reproductive capacity of brown frogs in the contaminated areas near the power plant. For example, it was stated that in spring 1987 more than 33% of frogs' eggs were completely or partially sterile, in comparison with a rate of 1.5% in a control population. This did not significantly alter in the next year. However, no direct relationship between radioactive contamination of the area and cytogenetic changes had been determined. It is reported that chromosomal aberration rates in the red bone marrow cells of frogs increased by a factor of 3–10 during 1986–1989. These later changes did not appear to be manifested as direct radiation effects on the population.

After the accident there were news media reports of severe birth defects in agricultural animals outside the 30 km zone in 1988–1989. When these claims were studied by a Ukrainian expert group, the frequency of the reported defects was found to be similar in the highly contaminated and the non-contaminated regions of Ukraine [38], which indicates that the birth defects were not likely to have been related to the direct effects of radiation. Possible confounding factors include, for example, the excessive use of fertilizers.

For aquatic ecosystems, fish generally appear to be the most radiosensitive organisms [32]. Despite considerable contamination, aquatic organisms have been shown to be quite tolerant of radiation at the levels resulting from the accident.

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[2] In the laboratory, doses of 50–170 Gy are typically used to sterilize insects in pest control programmes.

Investigations of the Chernobyl power plant cooling pond have shown that fish continued to produce viable offspring at doses of up to 8 Gy [39]. Benthic organisms were found to be the most seriously affected. This is not surprising since the highest levels of radioactive contamination in aquatic systems are found in the sediment (in the cooling pond, the dose rate was 0.1–0.2 Gy per day from bottom sediments at the end of April 1986). The size of the mollusc population *Dreissena polymorpha* was observed to be in decline but, at the same time, no effects were noted for the 31 fish species examined. If there were any surprises, they were in the unusually high transfer of radiocaesium from the water into fish [39].

Contamination of the environment

The seminatural environment

After the accident, it became clear that countermeasures taken in the settlements (urban environment) and the agricultural environment were not sufficient to control all the main sources of exposure for humans in the affected areas. The seminatural environment was an important contributor to the production of food (e.g. grazing of cattle, collection of wild foods, etc.) and to recreational activities for the local populations. Additional studies of the transfer mechanisms were conducted in order to be able to apply the best possible countermeasures.

Meadows

By impeding the migration of radionuclides into meadow grass, the main mechanisms for transfer of radionuclides into the food produced from grazing animals could be controlled. It was found that the movement of the soil contaminants is very dependent on the fallout characteristics (the physico-chemical form and the heterogeneity of deposition) and the concentration of the exchangeable radionuclides in the rooting zone (0–10 cm depth) of the plants. The downward migration of ^{137}Cs and ^{90}Sr in different types of meadows has been slow, leaving most of the contaminants available for root uptake in the top 5 cm of soil. In the first 2–3 years after deposition, the migration of ^{137}Cs was more rapid, but with time, these processes have slowed down by a factor of up to 6 [40]. Since 1991, the amount of ^{137}Cs transferred annually from soil to plant remains fairly constant with time.

The presence of clay, the organic content of the soil and soil moisture are the dominant factors influencing this process [38, 41]. Migration is faster in soil with high moisture levels and a high organic content (such as in meadows that flood and have peaty soil). On the basis of data from the 30 km zone and the three countries, the time (environmental half-time) that it will take for half the ^{137}Cs to move out of the top 10 cm of soil (and therefore decrease the radionuclide concentration in grass) ranges from 55 to 73 years (19–21 years effective half-life, with radioactive decay taken into account) for sandy and sandy loamy soils to 99–143 years (23–25 years effective half-life) for light loamy and heavy loamy soils in a dry meadow. For peat, it is dramatically faster, typically 15–20 years (10–12 years effective half-life).

The transfer of ^{90}Sr is faster than that for ^{137}Cs, with observed effective half-times of 7–12 years. The variation with soil type follows the same trends as for ^{137}Cs [42].

Forests

More than 30 000 km^2 of forests had ^{137}Cs deposition corresponding to more than 37 kBq/m^2 and about 1000 km^2 had deposition corresponding to more than 1.5 MBq/m^2 [40]. Forest canopies were very efficient in the initial interception of radioactive material from the contaminated air as it passed. Owing to weathering and shedding of leaves, the contamination dropped to the forest floor, after which the roots transported it back to the leaves [43, 44]. After 10 years, 90–97% of the contamination is still found in the top 5–10 cm of the forest soil (leaving 3–10% on the bark, wood and leaves/needles of trees). Of the total activity in trees, only 0.3–2.6% is found in the wood itself, and the highest concentrations are found in the most recent annual rings of the trunk. However, since fresh rings grow each year, the mean concentration in the wood is slowly increasing.

Forests are important for commercial use of the wood, as a source of food (berries, mushrooms, game, etc.), and for recreational purposes. In many local forests, doses to forest workers are typically elevated but not hazardous. Temporary permissible levels for the ^{137}Cs concentration in wood have been set at the national level, and in many local forests they may be exceeded unless changes are made in the production process for lumber. One countermeasure is to remove the most contaminated outer rings of the log before processing. Another is to use the wood for pulp, since the concentration of ^{137}Cs in bleached pulp is only about 1% of the original concentration in the raw wood. Some care has to be taken with the waste products from pulp mills (and also power/heating plants), which have concentrated levels of ^{137}Cs [45]. In many local forests, doses to forest workers are typically elevated but not hazardous.

Mushrooms growing wild in forests have traditionally been a staple ingredient in the diet in Belarus, Russia and Ukraine, and mushroom picking is a widespread recreational activity. In many areas, the long term consumption of mushrooms and wild berries is a significant exposure pathway owing to the relatively high concentrations of ^{137}Cs in these natural foods [46, 47] (see Fig. 5). The restriction of access to the forest and the use of public advisory campaigns can help to control doses. Another possible countermeasure is the normal boiling of mushrooms for 5–10 minutes, which will reduce the ^{137}Cs level by more than 50% [49, 50].

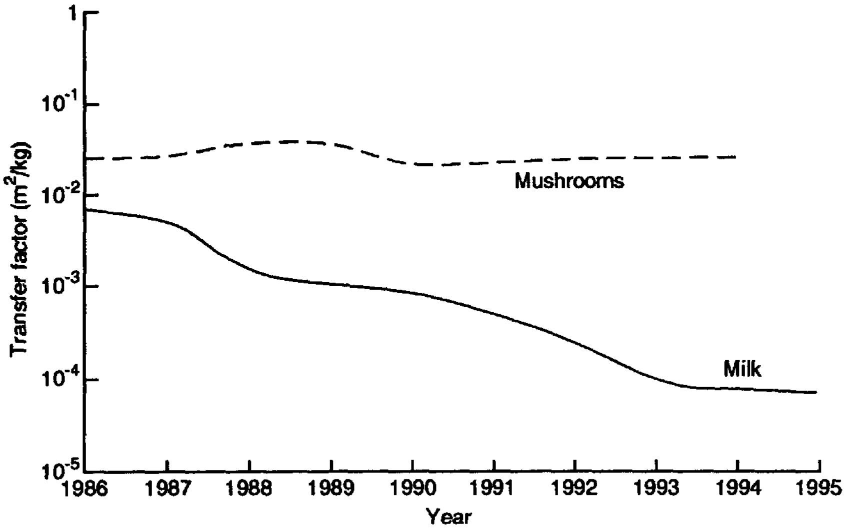

*FIG. 5. Transfer of ^{137}Cs from soil to milk and mushrooms (*boletus luteus*) in the Bryansk region as a function of time [48].*

Animals that graze seminatural pastures, forests or mountain areas (such as sheep, goats, reindeer, moose, roe deer and wild boar[3]) often produce meat with contamination levels above the nationally adopted limits for food in many areas of Belarus, Ukraine and Russia, as well as in Nordic countries and the United Kingdom [51, 52]. Countermeasures that cause minor environmental impacts, such as bans on hunting, changing of slaughtering times, the use of impregnated Prussian Blue salt licks and boli, and removal of animals to uncontaminated pastures, have been employed effectively in these areas. These types of countermeasures will be needed for long periods of time because the effective half-life for caesium in forest and seminatural ecosystems is relatively long. For example, sheep grazing in the mountains in Norway yield meat with an effective half-life for ^{137}Cs of about 20 years [46].

Another potential radiological risk would be that due to forest fires. Evaluations have shown that the doses from direct inhalation of resuspended particles would add only a small component to total exposure. Resuspended particles from forest fires could give rise to a transient increase in the ^{137}Cs levels in milk and meat of animals grazing on adjacent lands [53].

[3] For example, ^{137}Cs activity in the meat of wild boar hunted in the district of Bragin in 1994–1995 was 8000 to 60 000 Bq/kg.

The agricultural environment

Although the type of agricultural production varies, this is the predominant use of the land in the contaminated areas of the former USSR. The control of 'contamination' of the commercial production of food was a top priority, so monitoring and agricultural countermeasures were implemented. 'Contamination' is a generic term used by radiation protection specialists and radioecologists to describe any levels of artificially produced radioactive material. Action levels of activity in foodstuffs were established by national authorities in the three most affected republics and by international organizations. At contamination levels above these action levels, some countermeasure to reduce the concentration (or 'contamination') to below the action level needed to be considered. Table IV shows a selection of these action levels for ^{137}Cs in foodstuffs and drinking water. The levels in use in the three affected countries and in the European Union are in general below those established by the FAO/WHO Codex Alimentarius Commission and those adopted by the European Union for use after any future accident.

The local conditions (level of contamination, type of soils, soil moisture) and crop type had a profound effect on the reduction of contamination levels in food achieved by application of the countermeasures. For example, depending on the type of soil, the transfer factor between pasture and milk varies by several hundred [56].

TABLE IV. SELECTED ACTION LEVELS FOR ^{137}Cs IN DRINKING WATER AND FOOD PRODUCTS (Bq/L or Bq/kg)

Product	TPL 1993[a]	GALs FAO/WHO[b]	EC 1986[c]	MPLs (EC)[d]
Drinking water	20	1000[e]		1000
Milk	370[f]	1000	370	1000
Meat, meat products	600[g]	1000	600	1250
Grain, flour, cereals	370	1000	600	1250
Baby food	185	1000	370	400
Mushrooms	600	1000	600	—

[a] Temporary permissible levels adopted in Belarus, Ukraine and Russia in 1993 (with some exceptions) [12].
[b] Generic action levels for foodstuff moving in international trade [13].
[c] European Commission adopted levels of May 1986, extended several times since 1990 [54].
[d] European Commission maximum permissible levels for future accidents [54].
[e] WHO guideline for drinking water quality [55].
[f] In Belarus, 185 Bq/L is used.
[g] In the Gomel region of Belarus, 370 Bq/kg is used.

Immediately after the Chernobyl accident, the priority was to control the consumption of foods contaminated by ^{131}I, mainly milk and milk products. At this time there were strict restrictions on pasturing cows and harvesting of grasslands. After June 1986, owing to the short half-life of ^{131}I, the focus shifted to the longer term control of ^{137}Cs in crops to keep the food below permissible ('action') levels.

Since 1987, agricultural countermeasures have fallen into the following categories [57]:

- Organizational: monitoring of land and agricultural products; change in crops; changes in land use.
- Agrotechnical: ploughing.
- Agrochemical: liming of acid soils; application of potassium fertilizers; supplementing soils with natural sorbents.
- Veterinary and zootechnical: changes in diet; changes in feed before slaughter; removal of animals from pasture; use of caesium binders.
- Food processing: commercial or domestic home processing that removes radioactive contaminants.

Figure 6 shows the measured decline of ^{137}Cs in the food grown in the Bryansk region of Russia for milk and dairy products, meat and vegetables, as percentages of the total food that exceeded the national temporary permissible levels

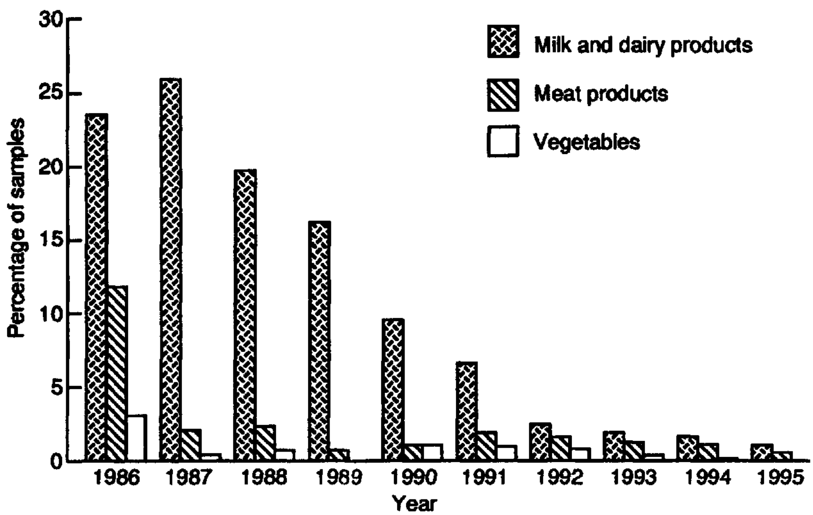

FIG. 6. Percentage of monitored food exceeding temporary permissible levels (TPLs) in the Bryansk region of Russia after the Chernobyl accident.

from 1986 to 1995. For milk, meat, potatoes and cereals, the countermeasures applied can account for about 60% of the decrease in the ^{137}Cs contamination [58]. The effectiveness and some of the costs for some of the countermeasures applied are shown in Table V.

The aquatic environment

After releases of radioactive material to the atmosphere, aquatic ecosystems are usually much less important for human exposure pathways than terrestrial systems. During the first week or so, direct deposition occurred onto rivers, lakes and seas. Within one month, the concentrations in the surface waters had fallen dramatically [26]. The material that had been deposited on land then slowly migrated into aquatic systems, where it ultimately was concentrated in sediments or migrated down to the sea. One of the most contaminated rivers was the River Pripyat, close to the Chernobyl plant. On 1 May 1986, the ^{131}I and ^{137}Cs concentrations in the river water at Chernobyl were 2100 Bq/L and 250 Bq/L, respectively. By 16 July, the levels had fallen to below the detection level for ^{131}I and to 7 Bq/L for ^{137}Cs, and by 1989 the ^{137}Cs concentration in water was about 0.4 Bq/L [59, 60]. The early countermeasures to protect water supplies have been criticized as having diverted significant national resources with extremely limited results [61].

Similar patterns have been observed in other rivers. The effective half-life of ^{90}Sr (about 6 years) in the River Pripyat fell more slowly than that of ^{137}Cs owing to the inflow of radioactive materials from contaminated land in the watershed area (peat bogs at times of flooding). The sediments of the Rivers Dnieper and Pripyat contain caesium, strontium, plutonium and americium (90% of the activity is due to ^{137}Cs) and, after storms and floods, ^{137}Cs and ^{90}Sr are detected in elevated amounts owing to the resuspension and transport of solids. Although fluctuations may be seen in the future, the lifetime effective dose to a person using the River Pripyat directly for drinking water is estimated at 0.4 mSv [59], which poses no hazard.

Of particular public concern has been the drinking water reservoir for Kiev city. The ^{137}Cs concentration in the reservoirs during 1989–1990 was only about 0.004–0.04 Bq/L. Levels of ^{90}Sr were about an order of magnitude higher. These levels are well below any safety criteria, even for normal non-accident conditions (see Table IV). Although the dose is trivial, the public perception of a significant hazard remains [39].

Even though the risk associated with drinking water obtained from contaminated surface water bodies is very small, the ^{137}Cs concentrations in fish from some rivers and lakes (e.g. Koyanovskoe Lake [62]) can exceed action levels owing to bioaccumulation, and hence countermeasures, such as fishing restrictions, may be needed. This is particularly important in lakes with low nutrient levels, common in

TABLE V. EFFECTIVENESS OF DIFFERENT TYPES OF COUNTER-MEASURES AND COSTS WHERE AVAILABLE [29]

Agrochemical countermeasures	Soil category	Crop type	Reduction in root uptake transfer	Total costs (1994 US $/ha)
Liming	Soddy-podzolic sandy, sandy loam	Barley, winter rye, oats, maize silage, potatoes, beetroots, vegetables	1.8–2.3	10.2–55.8
Increased application of P-K fertilizers	Soddy-podzolic sandy, sandy loam	Barley, winter rye, oats, maize silage, potatoes, beetroots, vegetables	1.2–2.2	
Application of organic fertilizers	Soddy-podzolic sandy, sandy loam	Barley, winter rye, oats, maize silage, potatoes, beetroots, vegetables	1.3–1.6	44.4–54.9
Application of clay minerals	Soddy-podzolic sandy, sandy loam	Barley, winter rye, oats, maize silage, potatoes, beetroots, vegetables	Dubious effectiveness, in light soils results mainly in 1.5–3.0-fold reduction in radionuclide accumulation in plants	
Combined application of lime, organic and mineral fertilizers	Soddy-podzolic sandy, sandy loam	Barley, winter rye, oats, maize silage, potatoes, beetroots, vegetables	2.5–3.5	84.6–111
Treatment type	**Product**	**Dosage**	**Reduction factor**	
Ferrocine	Milk	3–6 g per day	4–8	
	Meat (cows)	3–6 g per day	3–5	
	Meat (sheep)	0.5–1 g per day	3–7	
Ferrocine boli	Milk	2–3 boli per day	3–5	
Bifezh ferrocin	Milk	40 g per day	3–4	
Type of processing	**Product**		**Reduction factor (Bq/kg)/(Bq/kg)**	
Milk to butter	Milk		0.05–0.4	
Milk to cheese			0.5-2.5	
Milk to cream			0.6–2.2	
Milk to skimmed milk			0.9–1.0	
Soaking	Meat		0.5–0.7	
Salting			0.3–0.5	

northern Scandinavia, where conditions favour extremely high uptake of radiocaesium into fish. The observed ratio of ^{137}Cs concentration in freshwater fish and in the water of these lakes was of the order of 10 000 in 1991–1993 [63].

The surface water concentration of ^{137}Cs in the Baltic Sea in 1990 gave an activity of about 0.1 Bq/L [64] and fish contained about 15 Bq/kg [65]. These levels are falling very slowly with time because of the long mean residence time (20–30 years) of water in the Baltic Sea [66]. In the Black Sea, concentrations in 1990 were even lower, and the mean residence time of water is estimated to be 19 years [67]. At no time has there been or is there expected to be any hazard from contamination in the marine environment.

The human environment

The principal aim of any decontamination of residential and industrial areas is to reduce cost effectively the overall external dose of inhabitants or workers, with account taken of any negative effects on the environment. A significant proportion of the external dose received by people within and around their dwellings and places of work is due to activity in the soil or on other ground surfaces. As mentioned earlier, five years after the accident, about 90% of the caesium radionuclides was in the top 5–10 cm of undisturbed soil. Additionally, since the dose rate in air is derived from activity in the ground within a few tens of metres away, decontamination must be extended to 10–30 metres around the plot in order to significantly reduce exposures.

Large scale decontamination was done in 1986–1989 for about 1000 settlements, tens of thousands of residential and social buildings, and more than 1000 farms. This was done primarily by military personnel and included washing buildings with water or special cleaning solutions, cleaning residential areas, removing contaminated soil, cleaning and washing roads, and decontamination of open water supplies [68]. Depending on the decontamination technique, the dose rate over different plots was reduced by a factor of 1.5–15. However, the effectiveness in terms of the reduction of total external dose was typically up to only 30%. Observations of decontaminated plots after five years showed that there had been no significant recontamination [68].

Decontamination was mainly by removing the upper soil layer from populated areas, which is expensive. The volume of contaminated soil removed during decontamination of one village (population of several hundred persons), for example, was approximately 1000 m^3. The total amount of settlement decontamination waste exceeded one million m^3. These amounts of waste were usually transported to remote areas and buried in special storage far from settlements [68]. It is notable that more cost-effective approaches to decontamination, such as ploughing of soil to 30 cm, or the use of so-called 'skim and burial' or 'triple digging' ploughs which bury the upper soil layer at a depth of 30–40 cm in situ, were not used extensively, partly owing to lack of equipment. Studies performed in 1994–1995 have demonstrated that these methods produce practically the same dose reduction as topsoil removal with far lower costs and no large scale waste disposal problems [69].

Large scale decontamination, if carried out cost-effectively, can realistically achieve a reduction of 30% in annual external dose. Simple 'triple digging' techniques have not been carried out on a large scale, but they show potential for further dose reductions. Even a 30% reduction in annual dose is equivalent to waiting about ten years for natural weathering and decay processes to reduce the annual dose to the same level.

Resulting human exposure

Estimates of human exposure have been presented in terms of collective doses in Background Papers 2 and 3 for the purpose of discussing human health impacts. This section discusses the important pathways and nuclides contributing to human doses, how they change with time, and their relevance to countermeasures policy. Since the policy decisions made several years ago depended on the dose assessments carried out at that time, it is instructive also to review the influence that improvements in assessment methodology could have had on policy.

Several assessments have been made of the effective dose to the human population in the first year [24, 42, 70, 71] and, while they vary in the details according to the availability of local information, they all state that the contributions to the effective dose from inhalation and external gamma radiation from material in the initial plume were small. Moreover, they agree that the most important pathways of exposure to humans were the ingestion of contamination in milk and other foods (as ^{131}I, ^{134}Cs and ^{137}Cs), and external exposure from radioactive deposits (of ^{131}I, $^{103,106}Ru$ and $^{134,137}Cs$).

In the first few months, because of the significant release of the short lived ^{131}I, the thyroid was the most exposed organ. The dominant route of exposure for thyroid dose was the pasture-cow-milk pathway, with a secondary component from inhalation [72, 73]. The contribution from inhalation of short lived radioiodines other than ^{131}I is small, especially for young children, for whom the milk pathway, though, is extremely important [70]. The external dose pathway also makes only a small contribution to the thyroid dose. An accurate determination of individual human thyroid doses is highly dependent on whether or not countermeasures such as stable iodine prophylaxis and/or food bans were effectively taken.

Over the following nine years, the principal pathways by which humans were exposed were ingestion of ^{134}Cs and ^{137}Cs in food (especially milk) and the external dose [24]. Inhalation of resuspended material is negligible for the general population [74]. The doses from ingestion of food depend on consumption habits and on the contamination levels in local foods (which, as discussed earlier, varies significantly according to soil type as well as with time and according to the agricultural countermeasures that were taken). This has led to considerable variations between locations in the transfer factors from ground contamination to internal dose.

Levels of contamination in milk and meat, cereal and potatoes have fallen by an order of magnitude between 1987 and 1991–1992. However, the caesium content of many natural food products, such as berries and mushrooms, has not shown any significant reduction since 1986 other than by physical radioactive decay [48]. This component of the diet has a significant effect on the internal dose (see Fig. 7). The external doses for a given level of soil contamination are much less variable between settlements, although there can be a significant variation between individuals' exposures within a settlement (by a factor of up to three from the average) [28, 75].

The revised dose calculations were based on about one million whole body measurements [48] which were carried out in more than 300 settlements with higher contamination levels in Ukraine, Belarus and Russia (up to 1994). In the areas of lower contamination, measurements of radionuclide concentrations in foodstuffs were used to improve the methods of dose assessment.

Estimates of the breakdown of the total effective doses per unit ground contamination according to the external and internal components in urban and rural populations are presented by time period in Table VI. The top set of model estimates for internal dose do not take into account the countermeasures (which would have reduced the doses) or the consumption of wild foodstuffs (which would

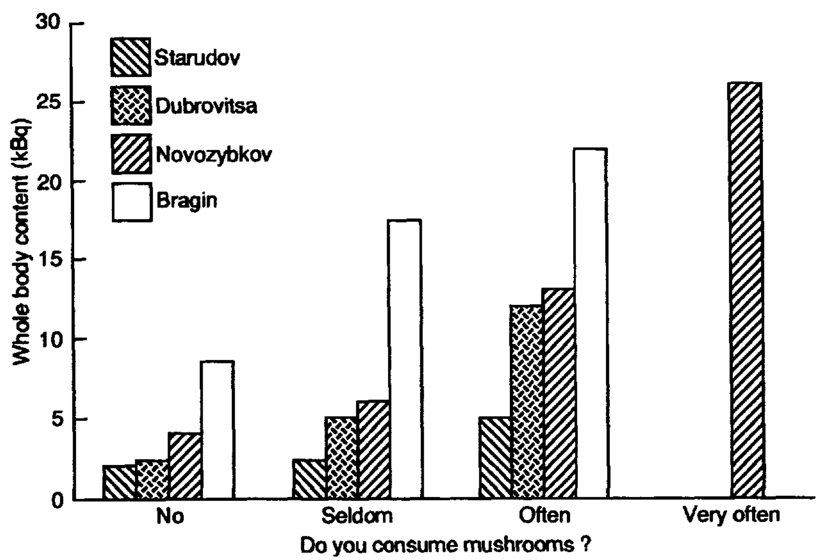

FIG. 7. Radiocaesium body burdens by grouping according to mushroom consumption at several study sites.

TABLE VI. RECONSTRUCTION AND PROGNOSIS OF THE AVERAGE EFFECTIVE DOSE DUE TO EXTERNAL AND INTERNAL EXPOSURE OF THE ADULT POPULATION IN THE INTERMEDIATE TO FAR ZONE (100 km < D < 1000 km) FROM CONTAMINATION AS A RESULT OF THE CHERNOBYL ACCIDENT

Exposure	Population group	Soil type	Effective dose per unit deposition of ^{137}Cs (mSv per MBq/m^2)			
			First year	1986–1995	1996–2056	1986–2056
External	Urban		8	23	17	40
	Rural		13	36	28	64
Internal[a]	Rural[b]	Turf-podzol	90/40	170/90	14	184/104
		Black soil	28/15	30/23	1/2	31/25

[a] The numerator is based on the current intake models [48], while the denominator is derived from whole body measurements [26].

[b] The internal doses in the numerator do not take into account the effects of countermeasures and it is assumed that no wild foods are consumed.

have increased the doses). The bottom estimates are based on whole body measurements made in the affected areas. It should be noted that about 60% of total external doses and over 90% of total internal doses have already been received by now, 1996.

A more realistic prognosis of the doses that a rural adult population would receive while living in an area with ground contamination of 0.6 MBq/m^2 (15 Ci/km^2) of ^{137}Cs in 1986 is given in Table VII. This takes into account both external and internal exposure from ingestion of ^{137}Cs and ^{90}Sr, inhalation of Pu radionuclides and ^{241}Am, with relatively high and permanent resuspension of soil. It was assumed that agricultural countermeasures and delivery of non-contaminated food would be discontinued in 1996. Because of the low content of ^{90}Sr in the material released by the accident and the fallout outside the 30 km zone, its contribution to the internal lifetime dose is less than 5–10% [42]. Natural food products contribute significantly to internal dose, but inhalation of transuranium radionuclides is not important, even for agricultural workers who breathe resuspended particles. (Inhalation of resuspended ^{238,239,240}Pu contributes less than 1% to the internal dose even for outdoor workers [77].)

It is notable that the present estimates for the average external doses are significantly lower than both the official Soviet estimates (129–156 mSv per MBq/m^2) and the estimates of the International Chernobyl Project (105 mSv per MBq/m^2) of 1990 [11].

TABLE VII. PROGNOSIS FOR ADULT EXPOSURE (1996-2056) FOR LIVING IN A RURAL AREA WITH GROUND CONTAMINATION LEVELS FOR ^{137}Cs OF 15 Ci/km^2 [a]

Exposure pathway	Population group	
	Total (mSv)	Critical[b] (mSv)
External	20	27
Ingestion	10	33
Inhalation	0.1	0.3
Total	30	60

Note: It is assumed that agricultural countermeasures and delivery of non-contaminated food will be discontinued in 1996.

[a] Soil surface contamination in 1986: 0.6 MBq/m^2; dominating soil type: turf podzol sandy soil.

[b] Outdoor workers living in wooden houses and consuming both agricultural and natural food [76].

The estimated total collective·effective doses (reported in Background Paper 3) for 1986–1995 for persons living in areas with a deposition density exceeding 15 Ci/km^2 (>555 kBq/m^2) and of 1-15 Ci/km^2 (37–555 kBq/m^2) are 10 000–20 000 man·Sv and 20 000–60 000 man·Sv, respectively (populations are 270 000 and 3.7 million, respectively).

The global effective collective dose commitment resulting from the Chernobyl accident has been estimated to be about 600 000 man·Sv. This dose is 2% of the total long term global collective effective dose received from all the nuclear weapons tests carried out in the atmosphere (30 million man·Sv) and 0.5% of the *annual* collective dose from natural background radiation (120 million man·Sv/year (based on an average 2.4 mSv annual effective dose for 5000 million people)) [24, 78]. If only the short term global collective effective dose from weapons tests is considered (without the long term dose of 5 million man·Sv from ^{14}C), the first percentage increases from 2% to about 12%.

Radiation protection policy

In 1990 the International Chernobyl Project concluded that the foodstuff restrictions should probably have been less restrictive on radiological grounds, but recognized that there were many social and political factors to be taken into consideration [11]; this is clear from the figures in Table IV.

Several authors [79, 80] have shown that the area of land concerned and the length of time that the land requires agricultural countermeasures or other restrictions are quite sensitive to the chosen action level. The collective dose saved by a countermeasure, on the other hand, is much less sensitive (Fig. 8). Thus, overestimating doses or selecting overcautious intervention levels significantly increases the area for which countermeasures are needed, but has a lesser effect on the collective dose saved. For example, if an intervention level is five times more cautious than need be, or if doses are overestimated by a factor of five, the hypothetical individual dose received by the 'critical person' is clearly a factor of five lower (A in Fig. 8). The collective dose saved by using the tighter criterion is about 60% higher (B in Fig. 8). However, the size of the area for which countermeasures are needed is increased by a factor of about eight.

Thus, pessimism will result in unnecessarily high costs, particularly concerning long lived radionuclides. For example, it is clear that the overestimation of the doses by a factor of two (for example because of conservative assumptions) leads to the extension of countermeasures by a period equal to the effective half-life (typically 10–20 years for ^{137}Cs).

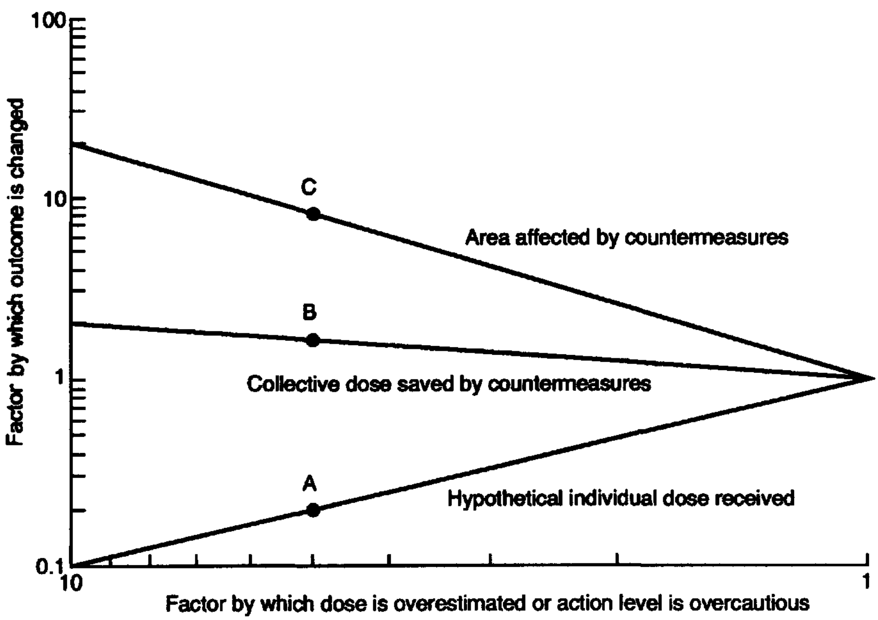

FIG. 8. The additional area of land for which countermeasures are needed and the collective dose saved for changes to an action level [79, 80].

4. FUTURE PROSPECTS

Looking to the future, the presence of the long lived radionuclides ^{137}Cs, ^{90}Sr, plutonium radionuclides and ^{241}Am in the soil will continue to contribute to the dose to humans. Table II shows the radioactive releases, activity levels prevailing today and projected activity in 60 years' time for key radionuclides. Caesium-137 is and will continue to be the dominant contributor to both external and internal dose over the next several decades. Strontium-90 will continue to cycle in the food-chain, and plutonium and americium will contribute mainly via inhalation and to a lesser extent via ingestion pathways. In general, to date, the population in the most affected areas has already received up to 60–80% of the total lifetime doses from the accident [26, 48].

The current annual dose for people in the areas with ^{137}Cs soil contamination of 0.6 MBq/m^2 and above is in the range of 1–4 mSv, and is predicted to fall to an average annual dose of about 0.5–1 mSv 60 years in the future [76]. These future doses may not warrant the continuation of active intervention, except in the more extreme case for consumption of local natural foods. This heightens the real need to re-evaluate the benefit of countermeasures as time passes.

From the studies of global fallout from the atmospheric nuclear weapons testing of the 1950s and early 1960s, we can expect a long term reduction of the ^{137}Cs and ^{90}Sr content in agricultural food products at a rate of 3–7% per year, depending on soil properties [9]. This will most likely not be the case with food derived from natural and seminatural environments, for which decline in activity is expected to be 2 or 3 times slower [48]. It is expected that the intake of ^{137}Cs by inhabitants of contaminated areas who do not consume local wild food will decrease on the average at 3–7% per year compared with the annual intake in 1993–1995, so it is expected that the committed internal dose for the entire time period 1996–2056 will be a factor of 15–30 times higher than the annual dose for the year 1996.

A subsequent decrease of the ^{137}Cs intake by consumers of local wild food is expected, at a rate of 2–4% per year; however, in areas where food restrictions were strictly followed in the past, there may be increases in doses owing to less strict adherence to the rules or as a consequence of economic difficulties [56]. The slow migration of ^{137}Cs into soil and radioactive decay will result in a decline in the external doses at a rate of 3–6% per year [48].

A prognosis of the doses a rural adult population would receive while living in an area that had levels of 0.6 MBq/m^2 (15 Ci/km^2) for ^{137}Cs in 1986 is given in Table VII. The prognosis takes into account both external doses and internal doses from ingestion of ^{137}Cs and ^{90}Sr, and inhalation of Pu radionuclides and ^{241}Am, with relatively high and permanent resuspension of soil. It was assumed that agricultural countermeasures and delivery of 'non-contaminated' food would be discontinued in 1996. Natural food products contribute significantly to internal dose;

however, inhalation of transuranium radionuclides is not serious, even for agricultural workers who breathe resuspended particles. In this population the external dose remains dominant for the average person, but for a higher exposed individual the internal and external doses are about equal. The hypothetical doses presented in Table VI show lower internal doses, because they are based on the assumption that wild foods were not consumed, and the soil with the highest transfer factor (peat) is not represented.

To generalize, in the projections for future doses over the long term (1996-2056), the collective dose to the most affected population is expected to increase by a further approximately 50% of the dose received over the last 9 years (1986–1995); or, in other words, two thirds of the total dose has already been received.

The future for the 30 km zone remains to be seen. Generally, the natural environment seems to be recovering from the initial high doses that caused some damage immediately after the accident. There is no evidence that the high chronic radiation doses in some specific localities are altering the local flora and fauna populations, and they do not seem to have inhibited survival. If anything, the absence of people from the area has probably had more significant effects, such as the growth of some populations [26]. Before rehabilitation of the area can be considered, more must be discovered about the physical and chemical forms of the fuel particles as they disintegrate and migrate into the environment. The potential problems of the buried waste at the Chernobyl site must also be considered in terms of possible local groundwater contamination.

The uncertainty about the future of the destroyed reactor and the sarcophagus leaves open questions regarding the possibility and magnitude of future radioactive releases. These issues are currently being considered in various international forums.

5. ISSUES ATTRACTING PARTICULAR PUBLIC INTEREST

Immediately after the accident and for several years subsequently, concerns about contamination of the environment were voiced in the media or by the public. The following issues evoked a high level of public interest.

It has been claimed that aquatic ecosystems such as the Black Sea and the Kiev reservoir could pose significant hazard to humans. Generally speaking, aquatic ecosystems contribute typically 10–100 times less to the dose derived from radioactive releases to the atmosphere (such as in the Chernobyl accident) than do terrestrial ecosystems. Furthermore, the actual doses from consumption of fish from the Black Sea [67, 81] and from drinking water from the Kiev reservoir are well below even normal permissible levels, and continue to fall [60].

Radioactive contamination of agricultural lands results in birth defects among animals. In various mass media in 1988–1989, it was reported that there had been a marked increase in birth defects (abnormal number of legs, anomalies in body organs, etc.) among newborn animals. Investigation revealed that the incidence of such anomalies in agricultural animals in non-contaminated areas did not differ statistically from analogous values for areas contaminated by the Chernobyl accident [38].

Importance of strontium and plutonium deposition. Owing to the low content of ^{90}Sr in the material released by the accident and the fallout outside the 30 km zone, the contribution of ^{90}Sr to the internal lifetime effective dose does not exceed 5–10%, according to intake calculations and direct measurements of ^{90}Sr in human bones (in autopsy samples). Similarly, the contribution from the inhalation of $^{238,239,240}Pu$ does not exceed 1%, even for outdoor workers [77].

Importance of resuspension. Resuspension of radioactive materials from the most contaminated zone does not lead to their significant transfer downwind. After 10 years, a conservative maximum of about a 6% increase in contamination at a distance of 100 m away from the contaminated area is seen. This excess declines to 2% at a distance of 10 km [82].

Importance of 'hot particles'. The key concerns in relation to hot particles were the potential increased health impacts in exposed populations. An IAEA Co-ordinated Research project to investigate the radiobiological impact of hot beta particles from the Chernobyl accident was held to address this. In the report from the second meeting, the majority of the participants "agreed that no evidence was presented that supported the concept that hot particles represented a greater risk than the same quantity of radioactivity uniformly distributed in the exposed tissue, whether it be lungs or skin". The long term environmental transfer of the radionuclides in the hot particles is still being investigated.

6. CONCLUSIONS

The initial release to the environment

Broad agreement has been reached among various estimates concerning the initial release (source term) caused by the accident. Most of the release was of radionuclides with relatively short half-lives. Releases to the environment of some radiologically important radionuclides — ^{131}I, ^{134}Cs and ^{137}Cs — are estimated now to have been higher by a factor of 2–3 than was estimated in 1986: current estimates are $(1.3–1.8) \times 10^{18}$ Bq, 0.05×10^{18} Bq and 0.09×10^{18} Bq, respectively. However, the reassessment of the source term has had no impact on the assessment of individual doses, which were based on the environmental or whole body measurements made in the affected areas.

The total amount of radioactive material still present in the environment after ten years has decayed to about 0.08 × 10^{18} Bq of long lived radionuclides, principally ^{137}Cs and ^{90}Sr, or about 1% of the total amount released. The overall pattern of contamination by these long lived radionuclides has remained essentially unchanged over the past ten years, with relatively little secondary transport of material.

Direct effects on plants and animals

The highest doses to plants and animals in the environment occurred immediately after the accident in parts of the 30 km zone. Contamination levels typically reached several tens of MBq/m^2 (thousands of Ci/km^2) in some localities, and external doses would have been of the order of several tens of grays in the first month from the short lived radionuclides. In the northern summer and early autumn of 1986, the dose rate at the soil surface dropped by a factor of 10–100 from the initial value.

Direct radiation injury of plants and animals was reported only in localized areas within the 30 km exclusion zone and within the first one to three years after the accident. Different organisms in the natural environment were exposed to high radiation doses, and the lethal doses for some radiosensitive ecosystems were reached. These lethal effects were seen in the coniferous forests near the plant and for some small mammals in this zone (5–30 km). For other ecosystems and individual plants and animals, no lethal effects were observed (even within the 30 km zone). By 1988–1989, in the zone of 3000 ha around the plant, damaged conifers had recovered their reproductive functions and are likely to recover fully. Herbaceous plants were little affected anywhere, but some abnormalities in other vegetation were found.

Severe direct effects of radiation at high doses were observed in some animals but were not necessarily significant in changing the health of populations. For example, cows consuming contaminated pasture close to the reactor in the early phase after the accident received thyroid doses in the range of hundreds of grays, resulting in atrophy and total necrosis of the thyroids of individual cows.

In some cases, the affected populations returned to normal in a few years, and in others, the significance of the consequences is still unknown. Chronic dose rates in some areas within the 30 km exclusion zone may have reduced the fertility of animals of some species, but it appears that other affected animal populations have already recovered. The overall significance of the observed changes in specific populations is difficult to determine.

There were media reports of severe birth defects in agricultural animals outside the 30 km zone in 1988–1989; however, the frequency of these reported defects was shown to be similar in highly contaminated and non-contaminated regions of Ukraine. No more severe effects observed in farm animals have been reported.

Long term effects on the natural populations would be a result of damages to the reproductive processes and hereditary damage. There has been some evidence that supports recovery; however, there is no general consensus at this time and it is difficult to come to a conclusion on the long term hereditary or ecological impacts. After ten years, caesium radionuclides are the major contributors to the low dose chronic irradiation. External doses in some isolated spots can still be of the order of 1 mGy per day; however, even in the 30 km zone, the natural environment seems to be recovering. Owing to the relocation of people from the 30 km zone, there have been some changes in the numbers and variety of animal and plant communities, but these changes have resulted from disuse of the land rather than radiation effects. Some natural populations have thrived as a result of the suspension of human interference.

Contamination of the environment

The seminatural environment

This category of the environment, between natural environments and agricultural land that is managed, may have a dominant influence on the future doses to the human population.

Key factors controlling the migration of radionuclides from topsoil into plants in meadow ecosystems are the clay and organic content of the soil and soil moisture. In general, the current migration rate is slow and steady. This is expected to continue over the coming decades, even as the level of radioactive material in the soil declines. The transfer of ^{90}Sr, with observed effective half-times of 7–12 years, is higher than rates found for ^{137}Cs, but the influence of different soil types is similar. This rate of transfer will be a central consideration in the long term use of meadows for the pasturing of cows.

Today, nearly all the contamination in forest ecosystems is found in the topsoil. The radiocaesium in trees is concentrated in the new growth rings owing to the soil–root transfer pathway. Forest fires have been identified as potential sources of the resuspension and redistribution of the ^{137}Cs currently remaining in the forests. Doses to workers from heavily contaminated wood and wood processing waste will need to be monitored. No cost effective countermeasures that would reduce the transfer of radionuclides into the trees have been found.

Food products from animals that graze in seminatural pastures, forests or mountain areas and wild foods (game, berries, mushrooms) gathered by the population will continue to show high ^{137}Cs levels over the next decades and are likely to be an important source of future internal doses. These foods may still be contaminated above the strict nationally adopted limits in areas of Belarus, Ukraine and

Russia; and also in Nordic countries and the United Kingdom. The effective half-time of ^{137}Cs in these areas is considerably longer than in agricultural areas. Sheep grazing on mountains in Norway, for example, show an effective half-time for ^{137}Cs in their meat of about 20 years.

The agricultural environment

In 1986, the concentration of some radionuclides (^{131}I, ^{137}Cs) in foods exceeded action levels adopted by international organizations (such as WHO). It was found that effective application of agricultural countermeasures could result in a significant reduction in the uptake of Cs and Sr into food. The reduction of contamination levels in food that was achieved by the countermeasures depended strongly on local conditions (level of contamination, type of soil, soil moisture) and crop type. For example, depending on the type of soil, the transfer factor between pasture and milk varies by several hundred. The appropriate application of these actions was very dependent on the particular site.

Safe and relatively simple and cheap measures include, for example: deep ploughing of surface contaminated soils; addition of fertilizers or other chemicals to agricultural lands; changing the crop type; changing feeding regimes and slaughtering times of cattle; the use of impregnated 'Prussian Blue' salt licks and boli to reduce the transfer of caesium to cattle; and removal of animals to uncontaminated pastures.

Monitoring and countermeasures will need to be continued for agricultural land, since food products are a main contributor to the dose to humans. However, much has been learned about the cost effectiveness of different countermeasures. It is expected that, with continued implementation, only very small amounts of food products with ^{137}Cs levels above the national temporary permissible levels will be found in the future.

The aquatic environment

Aquatic ecosystems have been shown to be tolerant of radioactive contamination, which gradually concentrates in sediments. Even in the Chernobyl plant's cooling pond, populations of only certain organisms were affected and no long term direct effects of radiation have been documented.

The radioactive material in freshwater aquatic systems is small compared with the total deposited. The activity in surface waters fell markedly within one month after the accident. Notwithstanding the public's perception, contamination levels in reservoirs are well below the criteria that would indicate a long term degradation in water quality. A lifetime effective dose resulting from using the River Pripyat directly for drinking water is estimated at 0.4 mSv. Fish, however, may accumulate radionuclides, and countermeasures may be necessary even in countries such as Sweden that are outside the areas of highest contamination.

Most of the radioactive material released was deposited over land; however, the marine environment may have received as much as (10–20) × 10^{15} Bq of the total ^{137}Cs. The highest concentrations were seen in the Baltic Sea and the Black Sea, which received about (3–5) × 10^{15} Bq and (2–3) × 10^{15} Bq of ^{137}Cs, respectively. However, the marine environment has never presented any contamination hazard.

Human exposure

The effective dose to the human population in the first year from inhalation and external gamma radiation from the initial plume was small. In subsequent years, the principal exposure pathways were external exposure from the deposited material and ingestion of radiocaesium in food (especially milk and potatoes). The transfer of contamination to different food products has varied by factors of several hundred because it is highly dependent on local soil type, time elapsed since the accident and the countermeasures applied in the specific area. Local ingestion doses have been affected accordingly. The dose assessment methods used previously have been improved, resulting in the downward revision of doses from the Soviet estimates and from the International Chernobyl Project estimates reported in 1990 [11].

The major part of the total external doses and nearly all of the internal doses to be expected from the accident have already been received. Residual average annual doses due to the accident in the three most affected countries are now comparable with the variation in doses arising from the natural background of radiation. Certain population groups such as young children are more at risk than others.

There is evidence that doses in some areas due to internal exposure have increased in recent years. This is thought to be due to the relaxation of restrictions and the increased consumption of mushrooms and natural foods. There are a number of different estimates (in many cases for specific regions) of the doses expected to be accrued over the next 60 years. In most cases the internal and external doses are expected to decrease, but the degree of reduction depends on the level of contamination and on the effectiveness of the countermeasures applied in each area. It seems probable that over the next 50 years foods from the forest ecosystem, particularly mushrooms, will remain a main contributor to internal dose, and it will be necessary to continue to discourage consumption.

The global effect of the accident has been to add very slightly to the natural background of radiation, with a long term collective dose of about 2% of that contributed by all atmospheric weapons testing. Significant continuing consequences outside the three most affected countries are limited to those due to elevated concentrations of caesium radionuclides in grazing animals in some habitats and in fish in certain types of lakes, which can significantly contribute to the doses of the populations that depend on those food sources.

Decontaminated urban areas

No significant recontamination of decontaminated urban areas has been observed. The effectiveness in terms of the reduction in total external dose was typically up to only 30%. Nevertheless, a 30% reduction in annual dose is equivalent to the effect of about ten years of natural weathering and decay processes. Other decontamination methods, such as simple 'triple digging' techniques, might be worth while in reducing doses in marginal territories to meet national criteria for rehabilitation.

Decontamination does give rise to a need for adequate disposal of the waste that is generated. The total amount of waste that was created by decontamination after the Chernobyl accident exceeded one million cubic metres. This does not present an external exposure problem, but migration from the numerous small waste disposal sites could potentially cause a secondary problem of groundwater contamination. The removal of large volumes of soil from decontaminated settlements was probably not the most cost effective means of large scale decontamination.

Radiation protection policy

The results over the past 10 years have shown that the correct implementation of countermeasures can significantly help to control the doses to the human population. However, as the International Chernobyl Project concluded in 1990 [11], the foodstuff restrictions should probably have been less restrictive on radiological grounds. The area of land and the length of time for which agricultural countermeasures or other restrictions are required depend quite sensitively on the national action level that is chosen. The collective dose saved by a countermeasure, however, is less dependent on this action level. Thus, very restrictive levels can lead to unnecessarily high costs, particularly in relation to long lived radionuclides. For example, overestimation of doses by a factor of two leads to the extension of countermeasures by an effective half-life (typically 10–20 years for ^{137}Cs).

The loss of use of land is expected to be gradually reversed over years or decades. The feasibility of rehabilitating evacuated areas in the future is being discussed on the basis of current dose estimates and evaluation of the effects of countermeasures. Resettlement of some evacuated lands could begin already, with the maintenance of localized restrictions, but other active intervention measures may not be necessary in the future. Resettlement may be hampered by the fear and mistrust of the population. One of the main lessons learned after the Chernobyl accident is how long lasting are the social impact of the initial actions taken after the accident and the enforcement of overly strict radiation protection policies in the longer term.

Future work

It can be concluded that: (1) at high radiation levels the natural environment has shown short term impacts, but significant long term impacts remain to be seen; (2) effective countermeasures can be taken to reduce the transfer of contamination from the environment to the human population, but these are highly site specific and must be evaluated in terms of practicality as well as their effects in reducing the population dose; and (3) the major part of the doses has already been received by the human population. If agricultural countermeasures are taken appropriately, the main cause of future doses will be the use of food gathered in, and recreational activities in, natural and seminatural ecosystems.

To improve the ability to assess present and prospective doses to the population and to apply the best radiation protection countermeasures, the following issues should be addressed:

- Would further study and monitoring of the migration of radionuclides into groundwater around the numerous small radioactive waste burial sites, in order to protect drinking water supplies in the future, help to allay the fears of the public?
- Why are dose estimates for internal doses from radiocaesium made on the basis of diet measurements and whole body counting often in disagreement? In general, the diet estimates have given doses which are 2–10 times higher than those obtained from whole body estimates.
- Would the processing of wild foods control contamination levels sufficiently to allow for the removal of restrictions?
- Can natural and seminatural ecosystems be completely rehabilitated in the next generation? Are there countermeasures that may help in the long term reduction of contamination levels in forests?
- What work on the cost effectiveness of countermeasures and long term intervention is needed to provide information for decision makers?

Although the answers to many questions have been found over the past ten years, there are further research issues that remain to be resolved and which would allow for better preparation to respond to any future accident, such as:

- The lack of movement of radionuclides from the top surface of the soil warrants further study.
- What will be the behaviour of 'hot particles' in the environment in the future as they continue to degrade?
- What is the role of fungi in the dynamics of radionuclide migration in forest soil, particularly for soil–plant transfer? Would knowledge of this role aid in the development of better models for forest ecosystems?

- Knowledge of the processes of migration for long lived radionuclides such as ^{90}Sr, ^{137}Cs and ^{239}Pu via food-chains on a long term basis (for periods of some tens of years and longer) is as yet incomplete.

The loss of amenity of the land in the affected regions has been difficult to evaluate owing to the changing economic and social conditions in Belarus, Ukraine and Russia over the last 10 years. Work to evaluate the impacts on society of the commercial and economic losses and changes in quality of life due to the loss of recreational use of the natural environment should continue.

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DISCUSSION ON BACKGROUND PAPER 5

Short presentation on the European Commission's forthcoming Atlas of Caesium-137 Deposition on Europe after the Chernobyl Accident[1]

Yu.A. IZRAEL (Institute of Global Climate and Ecology, Moscow, Russian Federation): The Atlas was compiled under a Joint Study Project of the Collaborative Programme between the European Commission and the Commonwealth of Independent States [of the former Soviet Union] on the Radiological Consequences of the Chernobyl Accident, which is a part of the Commission's Radiation Protection Research Action. The Atlas will summarize the results of numerous investigations undertaken throughout Europe to assess the extent of ground contamination caused by caesium-137 following the Chernobyl accident.

The Atlas will incorporate about 100 colour maps at a range of scales (from 1 : 200 000 to 1 : 10 000 000) which characterize the caesium deposition on Europe as a whole, within State boundaries and for zones where deposition levels are above 40 kBq/m^2 (this is said to apply to about 2% of European territory) and above 1480 kBq/m^2 (said to apply to about 0.03% of European territory), respectively (see, for example, the preliminary map for Europe, normalized to 10 May 1986, shown in Fig. 1).

According to the preliminary draft of the Atlas, "investigations have shown that around 6% of the European territory has been contaminated at more than 20 kBq/m^2 after the Chernobyl accident". In the draft Atlas it is stated that the total activity of deposited caesium-137 in Europe is 8×10^{16} Bq, and that this is distributed between countries as follows: Belarus 33.5%, Russia 24%, Ukraine 20%, Sweden 4.4%, Finland 4.3%, Bulgaria 2.8%, Austria 2.7%, Norway 2.3%, Romania 2.0%, Germany 1.1%, and other countries below 1.0%.

A paper on the Atlas was presented at the First International Conference of the European Commission, Belarus, the Russian Federation and Ukraine on the Radiological Consequences of the Chernobyl Accident, held in Minsk, Belarus, 18-22 March 1996.[2]

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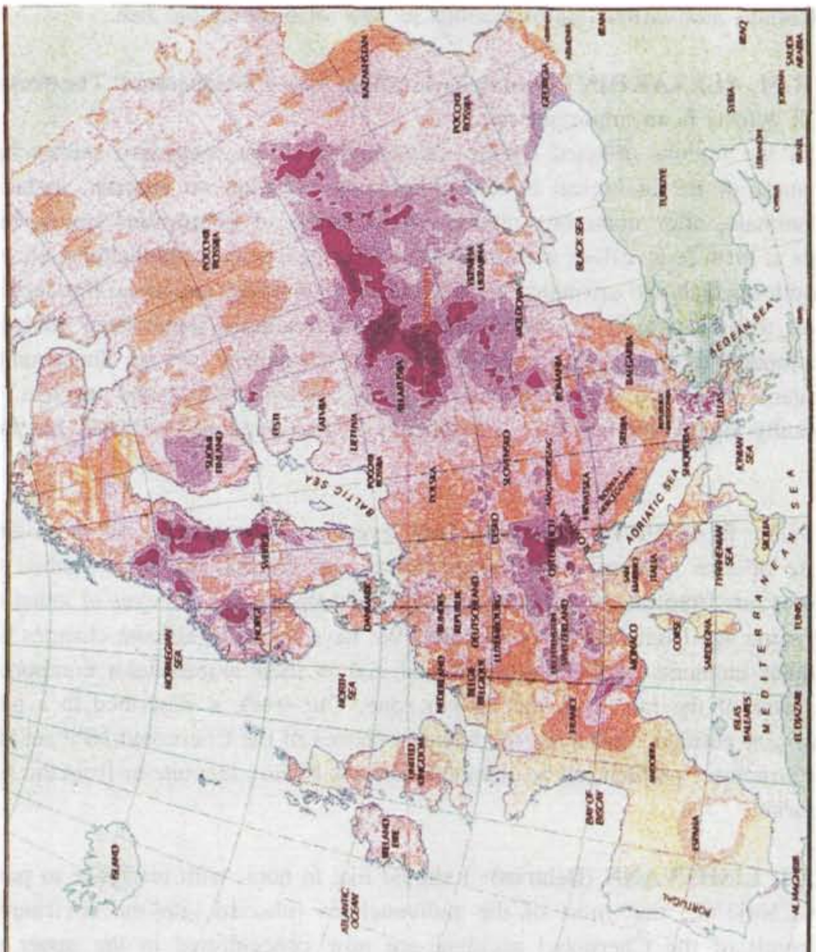

FIG. 1. Total caesium-137 deposition map for Europe. (© EC/IGCE, Roshydromet/Minchernobyl (UA)/Belhydromet, 1996.)

S. FERNEX (Switzerland): The claims that there have been no human birth defects as a result of the Chernobyl accident ignore findings of Prof. Lazuk and colleagues at the Institute of Inborn and Hereditary Diseases in Minsk, which has been maintaining a national registry since 1982.

In this connection, I should like to draw attention to a study, conducted by Prof. R.I. Goncharova and Dr. A.M. Sloukvin, of birth defects in carp in parts of Belarus contaminated by Chernobyl fallout. Birth defects have been found in 70% of hatchlings and various malformations in 70% of 6-month-old fish.

R.M. ALEXAKHIN (Russian Federation, Vice-Chairperson): The question of birth defects is an important one.

In the regions affected by the Chernobyl accident, extensive studies have been made of the biological effects of ionizing radiation on animals, including farm animals, after numerous reports in the media of deformities among farm animals at birth (e.g. calves with more than four legs, with exophthalmos, etc.) — deformities which are attributed by the media to ionizing radiation. Pre-accident data on the occurrence of abnormalities in farm animals have been analysed, and comparisons have been made between the frequency of such abnormalities in ''clean'' areas and their frequency in areas contaminated by the accident. No statistically significant increase in frequency in the contaminated areas has been noted.

N.N. BUSHUEVA (Ukraine [not even an Observer]): At the Filatov Institute of Eye Diseases and Tissue Therapy in Odessa, we have studied eye tissues of rats from the 30 km zone around Chernobyl, using the eyes of intact rats of the same age from Odessa as controls. We have found significant changes both in cellular elements of the tissues studied and in their extracellular components in the case of the rats from the 30 km zone. Our work is described in a paper (in Russian) entitled ''Influence of radiation factors of the Chernobyl NPP accident on eye structure'', which can be obtained from the Filatov Institute or from the Joint Secretariat.

I.I. LISHTVANN (Belarus): I should like to note, with reference to poster paper CN-63/62, that most of the radionuclides released into the environment as a result of the Chernobyl accident are now concentrated in the upper soil layers. Owing to sorption by the solid phase of the soils, they are mainly in the bound state, only an insignificant fraction being dissolved in water. The various forms of the radionuclides in the soils are in dynamic equilibrium among themselves.

Under the influence of various factors (both natural and anthropogenic), some of the radionuclides may enter the groundwater, be accumulated by plants and thus spread through the entire ecological chain.

When calculating radionuclide transfer processes, it is necessary to take into account the kinetics of the transition of the radionuclides from the solid phase to the water-soluble state and the dynamics of the temperature and moisture fields in the soils.

F.A. METTLER (United States of America): The present estimates of radioiodine releases from the damaged reactor are two to three times the early estimates. That being so, should not the thyroid dose [and potential cancer] estimates be revised?

A. BOUVILLE (United States of America, Chairperson): As the thyroid dose estimates are based on direct measurements performed with some 500 000 people in Belarus, the Russian Federation and Ukraine, the radioiodine releases are not relevant to those estimates.

I.G. GÖKMEN (Turkey): In the whole-body counting carried out after the Chernobyl accident, was only gamma radiation measured?

M.I. BALONOV (Russian Federation): No, alpha and beta radiation was also measured. More than a million measurements of whole-body caesium-134 and -137 levels were performed with transportable and stationary whole-body counters. More than 300 000 measurements of thyroid iodine-131 were performed in May–June 1986. In addition, several hundred autopsy samples of human tissues (mainly bones) were analysed for strontium-90 and several tens of autopsy samples of lung, lymph node, bone and liver tissues were analysed for plutonium. Increased concentrations of strontium-90 and plutonium were found in inhabitants of contaminated areas, but the contributions of these nuclides to the doses received were small compared with those of caesium-134 and -137.

I.G. GÖKMEN (Turkey): Were any determinations of lead performed?

B. PRISTER (Ukraine): In Ukraine, we measured lead concentrations in the skeletons of cattle in areas to the west of — and 50–400 km from — the Chernobyl NPP. No consistent variations in lead concentration were found.

I should like to take this opportunity to emphasize the importance of natural ecosystems. On private holdings in Ukraine, the hay for cattle is obtained from natural pastures. Owing to the particular characteristics to the peaty soil, a caesium-137 concentration of 300–500 Bq/L is now observed in cows' milk in a number of villages. This is disturbing people very much, and something must be done about it. The caesium-137 concentrations in many products from contaminated parts of Ukraine are in the range 100–250 Bq/kg, which is 10–30 times the concentrations found in western Europe and in the uncontaminated parts of Ukraine.

Yu.P. REVA (Russian Federation): At the Semenov Institute of Clinical Physics of the Russian Academy of Sciences, Moscow, we have — in collaboration with the Central Tuberculosis Research Institute of the Russian Academy of Medical Sciences, Moscow — produced a paper (in English) entitled "The finding of fungal melanin in bronchoalveolar lavage of liquidators of the Chernobyl Atomic Power Station accident". Copies can be obtained either from the Institute or the Joint Secretariat of the Conference.

Th. ABELIN (Switzerland): How many people are currently living in those parts of Belarus, the Russian Federation and Ukraine where the population is being advised not to consume wild food products from the local forests?

M.I. BALONOV (Russian Federation): About 200 000.

K. MÜCK (Austria): In Austria, during the years immediately after the Chernobyl accident we observed a decrease in the activity concentrations of caesium-137 in all foodstuffs at a rate equivalent to an effective half-life of about two years; similar decreases were observed in neighbouring countries such as Czechoslovakia and Germany and in the Bryansk and Kaluga regions. This half-life, which is much shorter than the effective half-life after atmospheric nuclear weapons testing, has resulted in activity concentrations which are a few tenths of a per cent of the 1986 values. What are the implications of such a rapid decrease for the early resettlement of people in the areas from which they were evacuated?

M.I. BALONOV (Russian Federation): The rapid decrease probably means that in some areas there is less need for agricultural countermeasures.

D.T.Y. CHEN (Switzerland): In the Conclusions of the Background Paper it is stated that "The majority of the total external doses and nearly all of the internal doses to be expected from the accident have already been received". I assume that this statement refers to doses received by single individuals and I would be interested in knowing what the accumulated dose over generations — which is important from the point of view of genetic effects — is expected to be.

M. DREICER (United States of America, Rapporteur): At present, most dose prognoses are for the period up to the year 2056, the Background Paper containing tables which show the dose expected for a given ground contamination level in the case of average urban or rural populations. Thus, the doses to people living in the area in question during the period up to the year 2056 can be generally estimated, but further work is needed as regards the period after the year 2056.

TOPICAL SESSION 6

Social, Economic, Institutional and Political Impact

Chairperson	J. LOCHARD, France
Vice-Chairperson	I. KENIK, Belarus
Scientific Secretary	G.N. KELLY, EC
Rapporteurs	I. KENIK, Belarus V. KHOLOSHA, Ukraine V. VLADIMIROV, Russian Federation

SOCIAL, ECONOMIC, INSTITUTIONAL AND POLITICAL IMPACTS*

Report for the Soviet Period

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First Deputy Minister,
Ministry of Emergency Situations,
Moscow, Russian Federation

1. THE CHERNOBYL ACCIDENT: SOCIAL AND ECONOMIC CONSEQUENCES

The Soviet Union was one of the major nuclear power countries. The world's first nuclear power reactor went into service there in 1954, after which a whole series of large nuclear power stations with different reactor types was built. Nuclear power's share of electricity generation rose to 12%.

The accident at the Chernobyl NPP (1986) was the most serious accident in the history of nuclear power generation, being accompanied by the ejection of a large quantity of radionuclides into the environment — with unfortunate ecological consequences. It claimed human victims, did serious harm to the economy and to morale and led to great anxiety within the Soviet population and in the world at large.

The accident disrupted normal life and economic activity in many parts of the Ukrainian SSR, the Byelorussian SSR and the Russian Soviet Federal Socialist Republic (RSFSR) and hampered electricity supplies to the economy. Agricultural and forest lands suffered, and work at industrial and agricultural enterprises (including collective farms) located in the zone with high radiation levels was halted. In the initial period after the accident 144 000 hectares of agricultural land were taken out of use, as were 492 000 hectares of forest land; 116 000 persons were evacuated and new homes had to be found for them. In 1986–1987 the following accommodation was found or built for the resettled population: about 15 000 apartments, hostel accommodation for over a thousand persons, and 23 000 houses; in addition,

* This paper was contributed not by the Joint Secretariat of the three sponsoring organizations (EC, IAEA and WHO) but by Belarus, the Russian Federation and Ukraine. The views expressed remain the responsibility of the named authors and were not endorsed by the sponsoring organizations. The paper was translated from Russian into English by the IAEA, but it was not edited.

about 800 social and cultural establishments were built (Voznyak, 1989). A new town — Slavutich — was built for the personnel of the Chernobyl NPP instead of the town of Pripyat, from which the population had been evacuated after the accident.

Serious harm was done to the development of nuclear power: the construction of new nuclear reactors at operating power stations was halted and the construction of new nuclear power stations in energy-poor regions was cancelled, which had a negative impact on the entire social and economic development of the country. Major financial, human, material and technical resources had to be assigned to the construction of the "Shelter" and to the elimination of the other accident consequences at the Chernobyl NPP itself, in the 30-km zone around it and in those parts of the Ukrainian SSR, the Byelorussian SSR and the RSFSR which had suffered.

2. INSTITUTIONAL AND POLITICAL IMPACT

After the first information about the Chernobyl accident had been received, the national leadership adopted the at that time traditional approach to the solution of unexpectedly occurring problems: on 26 April (i.e. the day of the accident) there was formed a Governmental Commission to Investigate the Causes of the Accident at the Chernobyl NPP; it was given the task of dealing with the situation at the site, taking measures to prevent further destruction and further harm to people and helping those who had suffered.

The Governmental Commission was made up of representatives of the relevant ministries and departments; it was headed by a Deputy Prime Minister. It was empowered to commandeer, for the purpose of eliminating the accident's consequences, all resources available within the country; its instructions were to be carried out by the executive authorities at the State, Republic and local levels. At the same time, it was an informal body, without precise rights or obligations (no decree about the Governmental Commission was published in the open press, and evidently none was ever adopted).

Given the particular complexity — for the political community and for the State at large — of the task of eliminating the accident's consequences, on 29 May 1986 the national leadership decided to establish a further extraordinary body vested with virtually unlimited powers — a Task Force of the Politburo of the Central Committee of the Communist Party of the Soviet Union (CPSU) for questions connected with elimination of the consequences of the accident. It was made up of four Politburo members, two candidate-members of the Politburo and a member of the CPSU Central Committee, and the USSR Minister for the Interior. It was headed by a Politburo member, the Chairman of the USSR Council of Ministers. In this case also, no decree was published and evidently none adopted. No allocation of responsibility for eliminating the consequences of the accident was made as between the Task Force and the Governmental Commission.

The most important questions regarding elimination of the accident's consequences were considered at meetings of the Politburo of the CPSU Central Committee (the highest deliberative organ in the country at that time) and of the USSR Government. Decisions were taken and directives issued. Individual questions were resolved at the level of the Supreme Soviet of the USSR in consultation with the trade unions.

Given the particular complexity of the work involved and the health risks arising from long periods spent near the Chernobyl NPP, the Governmental Commission, which was almost constantly in the town of Chernobyl during the period immediately after the accident, operated in shifts (with shift changes initially once a week, then once every two weeks and finally once a month). In the autumn of 1986, given the improvement in the radiation situation, it was decided to convert the Governmental Commission to Investigate the Causes of the Accident at the Chernobyl NPP into a Governmental Commission for Eliminating the Consequences of the Accident at the Chernobyl NPP, with a permanent staff and an operational arm in the form of a Department of the USSR Council of Ministers responsible for questions regarding the elimination of the consequences of the accident at the Chernobyl NPP. This Governmental Commission began holding its meetings in the town of Chernobyl only periodically, whereas the Task Force of the Governmental Commission was there constantly. In January 1988, the Task Force of the Politburo of the CPSU Central Committee was wound up, its work being continued by the Governmental Commission.

In 1989 there was formed a USSR Council of Ministers State Commission for Emergency Situations; to it were assigned the questions regarding elimination of the consequences of the accident at the Chernobyl NPP together with the existing Governmental Commission and its operational arm — the Department of the USSR Council of Ministers. In 1991 there was formed within the State Commission for Emergency Situations of the USSR Cabinet of Ministers a Committee for the Elimination of the Consequences of the Accident at the Chernobyl NPP which dealt with Chernobyl-related problems until the end of 1991 — the disintegration of the USSR.

The reaction to the accident and the emergency and recovery measures taken initially after the explosion at Unit 4 of the Chernobyl NPP clearly demonstrated how unprepared the responsible bodies, services and individuals were for such situations. Specialists have noted that almost no-one at or outside the Chernobyl NPP knew how to make an objective assessment of what had happened; all proved to be professionally and psychologically unprepared for dealing with the consequences of an accident on such a scale (Voznyak, Troitsky, 1993).

Clearly, the system of training for such events was inadequate. The actions of management and the distribution of functions among responsible individuals and services during emergency situations must be strictly regulated. The Chernobyl accident revealed numerous infringements of the rules, for both subjective and objective reasons. Characteristic features of the radiation incident were unpreparedness for such events and a lack of information, which was due firstly to considerations of secrecy and secondly to the incompetence and indecisiveness of the decision-makers. The result was fatalities and thousands of irreversible illnesses (Il'in, 1994).

The State, Republic and local authorities, the country's civil defence system and, to some extent, the scientific community and the public health system were taken unawares. The State did not properly fulfil its role of guarantor of the country's security.

In 1986, the country's civil defence system, responsible for ensuring that the population was protected against potential nuclear and chemical hazards, was oriented essentially towards wartime situations and concerned itself with preparing the population and the economy to survive and function in the event of a war in which the potential adversary used weapons of mass destruction — nuclear, chemical or bacteriological. The system was based on civil defence troops belonging to the USSR Ministry of Defence. These troops were among those armed forces to which insufficient attention was paid; their officers and equipment were "leftovers". Also, they did not possess sufficient authority when it came to mobilizing members of the population and material resources in the event of a major accident or disaster.

The first steps to limit the destruction at the Chernobyl NPP were completely unsystematic, dictated by the urgent need to save lives and localize the sources of radioactive emission. The organization of efforts to evacuate people, render first aid and decontaminate land bore the marks of "quick fixes" in an extraordinary situation.

Because of the prevailing atmosphere of secrecy in those days with regard to nuclear technology and to all major technology-related accidents, it was not possible to give the public the necessary information about the incident (accident, disaster) at the Chernobyl NPP, which in turn gave rise to rumours and panic in the population and produced a negative impact on the initial and subsequent efforts to eliminate the consequences of the disaster.

The supreme functionary in the USSR at that time, M.S. Gorbachev, General Secretary of the CPSU Central Committee, did not speak on State television about the accident at the Chernobyl NPP and its consequences until 14 May 1986 — 19 days after the accident. The communiqués in the mass media at that time were very restricted, not revealing the extent of the radioactive contamination of different areas or the consequences for the people living there. The main focus was on events which demonstrated the energy of the authorities in eliminating the consequences of the accident with a view to a restart of Units 1, 2 and 3 of the Chernobyl NPP before the winter of 1986–1987 set in.

All decisions taken at that time by the Task Force of the Politburo of the CPSU Central Committee and many of the decisions taken by the Governmental Commission were "classified", although in most of the documents there was no classified information of strategic or defence importance and the contents could have been published in the open press.

At that time significant measures were taken to eliminate the consequences of the disaster. The then highly centralized State was able to mobilize large military formations, the resources of over 40 ministries and departments and the country's best scientific brains. With minimum delay, the necessary financial resources, equipment and short-supply materials were sent to the regions which had suffered, as a result of which it was possible to significantly limit the losses due to the radioactive contamination of land, reduce the exposure of the population and protect its health. Owing to the paucity of information, however, in the public mind there developed the opinion that things were being done badly and that people had been left in the lurch by the "top brass" at the State level, and the resources made available for compensation were described by the population as "just enough for a funeral".

With time, the specific nature and the scale of the harm done to people and the environment by radiation created an objective need for a complete transition from a regime for dealing with extraordinary situations to a regime for purposeful and (most important) long-term State action to overcome the consequences of the disaster. On the whole, the taking of high-level decisions on assistance to the affected regions proceeded in accordance with a timetable worked out on a scientific basis, albeit often with significant delays.

The organization of the efforts to eliminate the consequences of the Chernobyl accident was based hierarchically on a rigid command system of administration: each year, at the governmental level, past decisions were refined and new decisions taken with regard to construction and decontamination activities, to improvements in public medical care, to the determination of special allowances, to the organization of compensation payments and to the resettlement of people from radioactively contaminated areas. At the same time, there was a lack of proper co-ordination among the ministries and departments assisting in the rehabilitation of contaminated areas and in the provision of welfare services for the people living in those areas, so that the decisions taken were not very effective and there were insufficient resources to back them up.

Not until 25 April 1990 (four years after the accident) did the Supreme Soviet of the USSR (the country's Parliament) consider the Chernobyl problem in formal session. In the decision taken by it, the Supreme Soviet, pointing to the inadequacy of what had been done to eliminate the consequences of the accident, stated that the situation which had developed by that time, was due largely to: an incorrect assessment — at all levels of State administration, both at the centre and locally — of the scale and consequences of what was in fact a global catastrophe; the unwarranted monopolization of investigations and classification of information relating to the radiation situation, especially in 1986; failure to provide the population with sufficient information; and the absence of a fully empowered State body responsible for measures to protect the population from the accident's consequences.

The country proved to be unable to properly comprehend what had happened and expeditiously resolve the scientific, social, psychological and legal problems involved, which had a negative impact on the development and implementation of a broad range of measures for eliminating the consequences of the accident.

The practice of administering complex long-term efforts like the elimination of the consequences of the Chernobyl accident showed that the country needed to switch to new scientific concepts, to a firm legislative basis and to a programmatic system of administration and that there was a need — in the country as a whole and in each of the Republics which had suffered — for a permanent body operating on a professional basis and accumulating experience relevant to the elimination of the consequences of major accidents and disasters.

In November 1989, the Supreme Soviet of the USSR, in a resolution on urgent measures for the ecological recovery of the country, approved the development of complex State programmes for elimination of the consequences of the Chernobyl accident in the RSFSR, the Ukrainian SSR and the Byelorussian SSR and requested the USSR Council of Ministers to examine those programmes, to take decisions in respect of the areas where it was competent, to submit at the autumn session of the Supreme Soviet of the USSR a single programme covering the USSR as a whole and individual Republics and to provide in the social and economic development parts of the 13th Five-Year Plans of the USSR and its Republics for the inclusion of the necessary financial, material and technical resources as separate line items.

During the formulation of the single programme it became clear that the scientific data and other information available in the USSR and elsewhere were insufficient as a basis for long-term decision-making, that being particularly so in the case of scientific data and other information relating to the effects on the human organism of protracted exposures to low-level radiation. It was therefore decided to include in the programme urgent measures designed to eliminate the consequences of the accident by 1993.

The USSR Council of Ministers finalized and, on 25 April 1990, the Supreme Soviet of the USSR approved a State programme — covering the USSR as a whole and individual Republics — of urgent measures to eliminate the consequences of the Chernobyl accident during the period 1990–1992. The programme was regarded as the initial stage of a long-term State programme. It was divided into a part relating to the USSR as a whole and State programmes for elimination of the Chernobyl accident's consequences in the Byelorussian SSR, the Ukrainian SSR, the RSFSR and the exclusion zone around the Chernobyl NPP during the period 1990–1995 (during the period 1990–1992 where urgent measures were involved). Owing to the disintegration of the USSR in 1991, the programme was not implemented to the envisaged extent. Using it as a basis, however, the Russian Federation, Ukraine and Belarus began to develop and implement their own Chernobyl programmes.

In April 1991, after many discussions and revisions, a "Concept for living in areas affected by the Chernobyl accident" was adopted, the basis for decision-making about the need for protective measures, about their character and scale and about compensation being the level of radioactive contamination and the exposure dose due to the accident. A person living in a radioactively contaminated area has a right to compensation, as provided for by legislation, in the form — inter alia — of special allowances and special social and medical care (USSR law of 1991).

A social support system finalized five years after the accident was enshrined in a USSR law on the social protection of citizens suffering as a result of the Chernobyl accident (USSR law of May 1991).

3. SOCIAL AND ECONOMIC IMPACT

The first measures taken after the accident by executive organs at the State, Republic and local levels were directed primarily to protecting the affected population against radiation and removing the immediate threat to life and health — particularly those of children and pregnant women.

At the same time, in connection with the evacuation measures provision was made for the affected people and enterprises to receive social and economic assistance. Machinery and other equipment, farm animals and other items of value were moved out of the radioactively contaminated areas to "clean" areas.

The State assistance to the affected areas in Russia, Ukraine and Belarus was provided from centralized financial, material and technical resources and focused mainly on: first, recovery and decontamination operations of various kinds; and, second, social support for the people living in the contaminated areas (their removal from such areas to ecologically clean areas, the provision of ecologically clean foodstuffs and the provision of appropriate medical care).

The affected population was compensated for the material losses due to evacuation — private homes, crops, possessions. On resuming operations in the areas to which they had been moved, enterprises (industrial and agricultural, including collective farms) were compensated for their material outlays; financial, material and technical resources were made available for the organization of production activities and for ensuring the employment of people who had been evacuated, some of whom were given jobs in enterprises already existing in the new areas.

In these areas, large-scale social measures were carried through for the benefit of the evacuees. Apartments were made available cost-free in towns and villages; where that was not possible, temporary accommodation was provided and crash programmes for the construction of houses and welfare facilities at rural locations were launched (as a rule, all the inhabitants of a given village were evacuated together to a new area). As a result, by the end of 1986 fairly normal living conditions had been created for the evacuated population.

In the areas with radioactive contamination levels higher than 15 Ci/km^2 (the so-called "stringent control zones"), from which the radiation safety standards did not require that the population be evacuated, the following social and economic measures were instituted: monetary payments (30 roubles/month) to each inhabitant for the purchase of "imported" foodstuffs instead of home-grown produce (meat, milk, vegetables, fruit, potatoes) temporarily barred for consumption; cost-free nurseries for children of pre-school age; and cost-free meals for school pupils.

As is well known, in the affected areas where people remained, large-scale decontamination operations have been carried out. Besides reductions in the radiation exposure of the inhabitants, there have as a result been some improvements in their social and economic situation.

For example, there have been complete clean-ups of contaminated villages; dilapidated private houses have been demolished and replaced by new ones; the roofs of peasant homes (usually old and with high levels of radioactive contamination) have been replaced by new ones made of long-lasting materials; peasant holdings have been provided with fences; well-equipped repositories have been built for domestic and radioactive waste; villages have been connected up to the gas supply network; water supply and waste water treatment systems have been installed; sewers have been constructed; wells have been drilled; roads, sidewalks, squares and yards have been surfaced with asphalt or concrete; bath-houses, laundries and other welfare facilities have been built. The work in question was done during the period 1988-89 (mainly during the warm season). As a result, the affected villages have improved in many ways from the point of view of public health and architecture, with a substantial upgrading of the welfare services being provided to the population.

The manpower and other resources of the Ministry of Defence and the building and road construction organizations of various Republics were widely drawn upon for the work in question. In addition, assistance was provided by the administrations of districts, autonomous republics etc. which did not experience radioactive contamination due to the Chernobyl accident.

By 1989, in the affected Republics of the former USSR there had begun to emerge a new socio-economic situation with regard to "the Chernobyl problem".

4. INTERNATIONAL REACTIONS

World public opinion was alarmed by the Chernobyl accident. In the first place, all countries had to face up to the question of the reliability of nuclear power plants and other nuclear facilities — especially countries possessing nuclear technology. As a result of a broad anti-nuclear movement, in many countries the construction of nuclear power reactors was halted and measures were taken to enhance the safety of reactors already in operation. Secondly, the territories of various countries (Poland, Norway, Italy, etc.) experienced appreciable radioactive contamination, so that in their case also measures had to be taken in order to eliminate the consequences of the accident; this applied particularly to the radioactive contamination of foodstuffs (vegetables, meat and milk).

Meanwhile, for a long time international relations regarding the Chernobyl accident were marked by an atmosphere of secrecy and isolation. It was not until 1989 that the Government of the USSR requested the IAEA to conduct an international expert study and assess the effectiveness of the measures being taken. The International Chernobyl Project, involving about 200 independent scientists from 23 countries and international organizations, was implemented during 1990. It was not until 25 April 1990 that the Supreme Soviet of the USSR addressed to the parliamentarians of all countries and to international organizations an appeal for assistance in resolving the problems caused by the Chernobyl accident.

As its 45th session, the UN General Assembly adopted a resolution (A/45/190, "International co-operation to address and mitigate the consequences of the accident at the Chernobyl nuclear power plant", 21 December 1990) in which it expressed profound concern about the ongoing effects on people's lives and health of the disaster at Chernobyl, which had had serious national and international consequences of unprecedented scale, and made an urgent appeal to all States members of the international community, intergovernmental and non-governmental organizations, the business community, scientific bodies and individuals "to continue to provide all appropriate support and assistance to the areas most affected by the accident at the Chernobyl nuclear power plant in full co-ordination and co-operation with envisaged or planned efforts of the United Nations system." The UN General Assembly has subsequently been considering the Chernobyl problem each year at its regular sessions.

5. LOSSES AND OUTLAYS CONNECTED WITH THE ACCIDENT

On the instructions of the USSR Government, the USSR Ministry of Finance published information provided by USSR ministries and departments and by the Councils of Ministers of the USSR, the Ukrainian SSR and the Byelorussian SSR regarding the annual direct losses and outlays due to the Chernobyl accident. For the period 1986–1989, the total of direct losses and outlays was — for all sources of financing — 9200 million roubles.

This information was presented officially to ECOSOC by the delegations of the USSR, the Ukrainian SSR and the Byelorussian SSR in a letter of 6 July 1990 addressed to the UN Secretary-General (A/45/342, E/1990/102, 9 July 1990).

The aforementioned total broke down as follows: 1986 — 3386.8 million roubles, 1987 — 2550 million roubles, 1988 — 1678.4 million roubles and 1989 — 1570.4 million roubles. In 1990, the expenditures from central USSR sources on eliminating the accident's consequences amounted to 3324 million roubles. In addition, the RSFSR, the Ukrainian SSR and the Byelorussian SSR assigned 1013.6 million roubles of their own resources for that purpose. In the 1991 State plan for the USSR, 10 300 million roubles from central sources were earmarked for elimination of the consequences of the Chernobyl accident. Owing to the disintegration of the USSR, however, the financing was taken over by the individual USSR Republics concerned. For the period 1986-1991, the total direct losses and outlays amounted to 23 837 million roubles.

These expenditures were accounted for, inter alia, by: losses of capital assets; production losses in agriculture and related sectors; actions to eliminate the consequences of the accident; the construction of homes, welfare facilities and roads; forest protection and water conservation measures; soil decontamination and treatment with lime; compensation to agricultural enterprises, co-operatives and the population at large for losses of crops, animals and possessions; removal costs; and payments of daily allowances to the population.

They were covered: from the USSR budget and the budgets of individual Republics; through payments made by the State insurance company to individuals, agricultural enterprises and co-operatives; and from voluntary contributions of individuals and organizations (altogether 544 million roubles) paid into account No. 904920, "Assistance fund for eliminating the consequences of the accident at the Chernobyl NPP". Resources in foreign currencies were also received; during the period 1988-1989, a total of 2.97 million roubles was received in foreign currencies from various sources, contributions worth 2.2 million roubles being made in convertible currencies.

Report for the Russian Federation

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1. SCALES OF CONSEQUENCES

1.1. Areas affected by radioactive contamination

Radioactive contamination of the territory of the Russian Federation as a result of the Chernobyl accident was recorded first on 29 April 1986 in the Bryansk region and then in the Tula and Kaluga regions. In the days that followed increased levels of radiation were noted in the Smolensk, Lipetsk and Orel regions. Radioactive contamination was measured almost every year after the accident. First of all, areas with a ^{137}C (main dose-forming radionuclide) contamination density above 15 Ci/km^2 were determined, then areas with 5–15 Ci/km^2 and lastly areas with 1–5 Ci/km^2. As of January 1995, the total area of the Russian Federation contaminated by ^{137}Cs as a result of the Chernobyl disaster with a density above 1 Ci/km^2 was 57 650 km^2, and the territories of 19 constituent units of the Russian Federation were contaminated, of which five have comparatively small contaminated areas (see Table I).

1.2. Number of persons affected

About 300 000 citizens of the Russian Federation ("liquidators") took part in the work on mitigating the consequences of the accident in the exclusion zone. In 1986, 181 inhabitants were evacuated from four small villages in the Bryansk region. Subsequently, after appropriate decisions were taken by the Government and the Law on Social Protection of Citizens was adopted, about 50 000 inhabitants were resettled and moved out voluntarily from the contaminated areas of the Bryansk region and also partly from the Tula, Kaluga and Orel regions. The number of persons residing in the contaminated areas is 2687.

1.3. Distribution of the population as a result of contamination of the territory

Considering the non-uniformity of radioactive (caesium) contamination of the territory of the Russian Federation and its distribution in "spots" with different contamination levels, the contaminated zones defined by law are being constantly determined. The number of settlements identified was 7096 in 1992 (2 310 000 inhabitants) and 7661 in 1995 (2 687 000 inhabitants) in the above zones of 14 constituent units of the Russian Federation (see Table II). The accurate

TABLE I. TERRITORY OF THE RUSSIAN FEDERATION CONTAMINATED BY CAESIUM-137 AS A RESULT OF THE CHERNOBYL ACCIDENT
(status as of January 1995)

Regions/republics	Area of region/republic (km^2)	Areas contaminated by caesium-137 (km^2)				
		1-5 Ci/km^2	5-15 Ci/km^2	15-40 Ci/km^2	over 40 Ci/km^2	Total
Regions						
1. Belgorod	27 100	1 620				1 620
2. Bryansk	34 900	6 750	2 628	2 130	310	11 818
3. Voronezh	52 400	1 320				1 320
4. Kaluga	29 900	3 500	1 419			4 919
5. Kursk	29 800	1 220				1 220
6. Leningrad	85 900	850				850
7. Lipetsk	24 100	1 690				1 690
8. Nizhni Novgorod	74 800	250				250
9. Orel	24 700	8 840	132			8 972
10. Penza	43 200	4 130				4 130
11. Ryazan	39 600	5 320				5 320
12. Saratov	100 200	150				150
13. Smolensk	49 800	100				100
14. Tambov	34 300	510				510
15. Tula	25 700	10 320	1 271			11 591
16. Ulyanovsk	37 300	1 100				1 100
Republics						
17. Mordovia	26 200	1 900				1 900
18. Tatarstan	68 000	110				110
19. Chuvashia	18 000	80				80
TOTAL		49 760	5 450	2 130	310	57 650

TABLE II. NUMBER OF SETTLEMENTS AND NUMBER OF INHABITANTS LIVING IN AREAS CONTAMINATED AS A RESULT OF THE CHERNOBYL ACCIDENT
(status as of June 1995)

	Zone where the inhabitants enjoy preferential social and economic status (1–5 Ci/km^2)		Zone where the inhabitants have the right to be evacuated (5–15 Ci/km^2)		Evacuation zone (15–40 Ci/km^2)		Total in contaminated area	
	Number of settlements	Number of inhabitants (in 1000s)	Number of settlements	Number of inhabitants (in 1000s)	Number of settlements	Number of inhabitants (in 1000s)	Number of settlements	Number of inhabitants (in 1000s)
Republic								
Mordovia	28	17.9					28	17.9
Regions								
Belgorod	94	77.8					94	77.8
Bryansk	768	236.3	284	147.0	279	90.8	1331	474.2
Voronezh	103	40.4					103	40.4
Kaluga	313	79.5	135	15.4			448	95.0
Kursk	273	140.8					273	140.8
Orel	2100	392.1	57	17.8			2157	409.9
Leningrad	44	19.5					44	19.5
Lipetsk	145	71.0					145	71.0
Ryazan	726	199.5					726	199.5
Tambov	29	16.1					29	16.1
Tula	1741	769.3	312	166.8			2053	936.2
Penza	190	130.6					190	130.6
Ulyanovsk	40	58.0					40	58.0
Total	6594	2249.3	788	347.2	279	90.8	7661	2687.4

Note: The number and list of settlements are being revised by the Government.

determination of radioactive contamination of individual settlements in the Russian territory is continuing. Proposals have been made by the administrations of the constituent units to include additional settlements in the zone of habitation with preferential socio-economic status (these proposals are under consideration).

2. ECONOMIC CONSEQUENCES

2.1. Annual budget allocated for the purpose of mitigating the consequences of the Chernobyl accident

The resources for mitigating the consequences of the accident are provided under three federal programmes. During 1992–1995 the amount spent on financing the "Unified State programme on Protection of the population of the Russian Federation against the consequences of the Chernobyl disaster for 1992-1995 and for the period up to 2000" was 3 064 000 billion (10^9) roubles (at the respective years' prices). During this period 176.8 billion roubles were allocated to the Federal programme "Children of Chernobyl", and 108.5 million roubles from the Federal budget in 1995 to the Federal programme "Housing for the Liquidators". Under all the programmes on mitigating the consequences of the accident the amount spent in 1992-1995 was 3349 billion roubles or, according to the official exchange rate at the end of each year, US $1155 billion. These expenditures over the years as a percentage of the GDP and the Russian Federation State budget tend to decrease (see Table III).

2.2. Sources of funds

The main source of financing the measures on mitigating the consequences of the accident is the Federal budget. For the programme "Housing for the Liquidators" funds are also made available from the budgets of the Russian Federation's constituent units and extrabudgetary sources. A part of the expenditure on social payments is covered by the Social Insurance Fund of the Russian Federation (in 1994, 63.6 billion roubles were allocated from this fund or 9.8% of the expenditure on social payments in this year).

2.3. Use of the Chernobyl budget

The resources are being used strictly in accordance with the various heads of the Chernobyl programmes. The expenditures are divided into the following heads: current expenditures (practical measures), capital expenditure and payment of compensation and benefits. The financing of the individual parts of the Unified Programme in 1992-1995 is shown in Table IV. Of the practical measures, the main

TABLE III. EXPENDITURE ON THE ELIMINATION OF THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT AS A PERCENTAGE OF THE GROSS DOMESTIC PRODUCT AND THE CONSOLIDATED STATE BUDGET

Programmes	Expenditure on elimination of the consequences of the accident (10^9 roubles)	Percentage of GDP	Percentage of State budget
1992 ("Chernobyl" and "Children of Chernobyl" programmes)	67.0	0.35	1.12
1993 ("Chernobyl" and "Children of Chernobyl" programmes)	353.4	0.2	0.61
1994 ("Chernobyl" and "Children of Chernobyl" programmes)	1192.4	0.19	0.51
1995 ("Chernobyl", "Children of Chernobyl" and "Housing for the liquidators" programmes)[a]	1736.1	0.1	0.38

[a] The data for 1995 are provisional.

focus is on those associated with the protection of health of the citizens and provision of socialized medical care (44.6% of current expenditure) and on the financing of measures to reduce the dose burden on the population, including measures relating to the agro-industrial complex and forestry (24%). In the case of capital expenditure, the bulk of the expenditure is on construction for non-industrial purposes (74.8%). This includes construction of housing, medical institutions, schools and children's pre-school institutions. The programmes could not be financed fully because of the complex economic situation in the country and shortage of budgetary resources.

In the Federal programme "Children of Chernobyl" the main attention was devoted to the provision of medical assistance to children and pregnant women and psychological help to children. The financing of its main parts is shown in Table V.

From the 1995 Federal budget 108.5 billion roubles were appropriated for the financing of the "Housing for the Liquidators" programme. The resources are divided among 85 constituent units of the Russian Federation in proportion to the number of liquidators residing in them; first of all, provision was made for the families of the invalid liquidators and the families of the deceased liquidators requiring improvement in their living conditions. Moreover, a part of the expenditure is covered from the budgets of the constituent units (republics, territories, regions and autonomous areas) and extrabudgetary sources.

TABLE IV. ACTUAL BUDGETARY EXPENDITURE ON MEASURES PROVIDED FOR UNDER THE UNIFIED STATE PROGRAMME FOR THE PROTECTION OF THE POPULATION OF THE RUSSIAN FEDERATION FROM THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT
(at the prices of the corresponding years, millions of roubles)

Expenditure	1992	1993	1994	1995	1992–1995	
					Total (millions of roubles)	Percentage
1	2	3	4	5	6	7
I. Operating expenses (practical measures) including:	4 471.6	14 209.7	49 092.3	30 509.7	98 366	100.0
1. Public health protection and provision of specialized medical care	886.5	6 985.8	23 251.9	12 826.8	43 951	44.6
2. Monitoring of the radioecological situation and establishment of information support system	294.3	905.6	2 963.2	1 689.8	5 853	5.9
3. Measures for the exclusion zone and the area of compulsory evacuation	29.1	75.3	232.7	71.9	409	0.4
4. Measures to reduce the dose commitment to the population, including agro-industrial and forestry measures	1 231.2	2 137.9	11 166.6	9 216	23 752	24.0
5. Expenditure on the social and socio-psychological rehabilitation of the population	287.0	1 332.2	3 061.2	740	5 420	5.5
6. Economic rehabilitation of the areas	840.5	1 188.1	3 961.6	2 247.3	8 238	8.3
7. Scientific support	1 159.8	928.1	3 077.7	1 555.2	6 721	6.8
8. International co-operation	—	30.7	109.3	79.3	219	0.2
9. Co-operation with public organizations and information support for the population	6.2	43.7	105.9	213.7	370	0.4
10. Management of work on the implementation of the programme measures	—	68.6	65.7	32.8	167	0.2

1	2	3	4	5	6	7
11. Information and analytical support	—	513.6	1 096.5	1 917.9	3 528	3.6
12. Reserve[a]	37.0	—	—	—	37	0.1
II. Capital investments	39 787	173 818	41 648	481 643	1 112 096	100
Including:						
In the production sector	18 346	63 867	128 160	69 702	280 075	25.2
In the non-production sector	21 441	109 951	288 688	411 941	832 021	74.8
III. Social protection of the population (payment of compensation and granting of privileges)	21 900	156 340	644 101	1 031 292	1 853 633	—
Total for the programme	66 159	344 368	1 110 042	1 543 526	3 064 095	—

[a] The reserve was distributed among the sections of the programme and used for unforeseen expenditure.

TABLE V. ACTUAL BUDGETARY EXPENDITURE ON MEASURES PROVIDED FOR IN THE FEDERAL PROGRAMME "CHILDREN OF CHERNOBYL"
(at the prices of the corresponding years, millions of roubles)

Expenditure	1992	1993	1994	1995	1992–1995	
					Total (millions of roubles)	Percentage
I. Operating expenses (practical measures) including:	884.5[a]	1 577.2	7 825.4	14 791	25 079	100.0
1. Provision of medical care to children and pregnant women		502.2	2 200.4	5 607.5	8 310.1	34.3
2. Measures for the provision of uncontaminated food to children, pregnant women and nursing mothers		49.0	452.9	1 279.3	1 781.2	7.4
3. Treatment of children		338.2	393.3	1 006.4	1 738	7.1
4. Medical and social support for disabled children in boarding schools		63.6	432.6	2 642.6	3 139	12.9
5. Psychological support for children		519.6	3 881.6	3 697.9	8 099	33.4
6. Scientific support		104.5	464.6	557.7	1 127	4.9
7. Reserve					—	—
II. Capital investments	—	7 465	74 492	69 791	151 748	—
Total for programme	884.5[a]	9 042.2	82 317.4	84 582	176 827	—

[a] The operating expenses were divided among the regions without a breakdown in terms of the specific sections, the capital investments in 1992 were allotted from the regional budgets.

2.4. Effect on economic activity

The Chernobyl disaster had an adverse effect on the economic activity of the regions affected by radioactive contamination, especially those most affected — Bryansk, Kaluga, Orel and Tula regions. The industries that exist in these regions are machine-building, light industry, food processing and chemical (Tula region). Here we note that the decline in industrial production is greater than in the country as a whole. While the fall in industrial production in the Russian Federation was 21% in 1994 and 3% in 1995, the corresponding figures are 36% and 9% in the Bryansk region, 30% and 13% in the Orel region, 27% and 6% in the Kaluga region and 28% and 10% in the Tula region. Most industrial enterprises in these regions are characterized by under-utilization of capacities, problems of product marketing, lack of assured State orders and delays in the payment of salaries.

The effect of the disaster is felt still more on agricultural production since a large part of the agricultural produce is obtained from the contaminated areas. Thus, in the Bryansk region the contaminated area occupies 31.8% of the total area of the region, while it produces up to 53% of cattle and poultry meat and 47% of milk. Up to 47% of the total population of cattle and up to 63% of the total population of pigs in the region are concentrated here. In the Orel region, 38.1% of the contaminated area accounts for 45% of the meat production and 58% of the milk production and in the Tula region (45.1% of the contaminated area) up to 65% of the meat and milk production.

In the contaminated agricultural land, meadows and pastures it is necessary to apply special costly improvement measures and to use special techniques for the management and feeding of animals so as to reduce the radiation contamination of agricultural produce to authorized levels. The measures taken in the first few years after the accident, such as special treatment of agricultural land, application of increased doses of potassium and phosphorus fertilizers to contaminated soils, liming of these soils where necessary, cultivation of meadows and pastures for cattle, supply of concentrated feeds from State reserves and other measures in this direction, made it possible not only to obtain high-quality products but also to raise to some extent the economic level of farming by increasing the crop yield of fields and the productivity of livestock farming.

At present, grain, potato, vegetables, fruit and berries which are clean within authorized levels and practically clean animal produce are being obtained from the entire radiation contaminated area of the Russian Federation. It is only in the most contaminated south-western districts of the Bryansk region (15–40 Ci/km^2) that less than 1% milk and less than 0.1% meat have higher than the authorized levels of radiation contamination. Such cases occur generally at individual peasant farms which do not comply with the recommendations on the management and feeding of animals. At the same time, the agro-improvement measures should be applied on contaminated agricultural land for a fairly longer time. Any shortening of this time will raise the content of radionuclides in the produce and possibly make it unsuitable should the levels authorized by health standards be exceeded.

In recent years less attention has been paid to these problems and the Federal budget appropriations for agricultural production in contaminated areas have been reduced substantially. This has led to a fall in the volume of production, decrease in yield and poorer economic performance for rural commodity producers.

The grain harvest for Russia in 1995 was on an average 78% of the 1994 level, while it was still lower in the Bryansk region — 75%, 73% in the Kaluga region and 72% in the Orel region. If the grain harvest per hectare of arable land in 1994 in all the four regions was higher than the average for Russia, that in 1995 in the Bryansk and Kaluga regions was lower than the Russian average. Meat production declined by 13% in 1995 as compared to 1994 in Russia. During this period the decline was 11% in the Bryansk region, 13% in the Orel region and 13% in the Tula region. In the Tula region milk production dropped substantially in 1995. One of the most important socio-economic indicators of the situation in the region is the volume of retail commodity turnover. While for Russia as a whole the total volume of retail commodity turnover at fixed prices fell by 7% in 1995 as compared to 1994, the fall was 27% in the Bryansk region, 22% in the Orel region and 14% in the Tula region during this period.

The agricultural producers of these regions are compelled to carry out intensive examinations of cattle in the contaminated areas for such diseases as tuberculosis and leukosis. In all regions of the Russian Federation, every year about 1.8 million examinations are carried out, of these 260 000 in the Bryansk region, 420 000 in the Orel region and 430 000 in the Tula region. Examinations are also carried out to detect radioactive contamination of the wool coat of sheep in the regions where the sheep stock has remained unchanged. Under the developing market conditions in Russia the commodity producers in the affected areas encounter great difficulties in selling their agricultural produce grown in the contaminated areas.

3. REACTION OF THE POLITICAL, LEGISLATIVE AND ADMINISTRATIVE AUTHORITIES TO THE CHERNOBYL ACCIDENT

3.1. Effect of the accident at the political level

In the post-Soviet period the Chernobyl problem in the Russian Federation lies within the sphere of interest of the President, the Parliament and the Government. In particular, this became apparent in the first years of the new Russian State. The affected areas, first of all the Bryansk region, were visited in 1991–1993 by the President, the Chairman of the Supreme Soviet, the Head of the Government and other State and Government officials. The Chernobyl topic received wide coverage in the mass media. During this period a number of State and Government documents were adopted on the Chernobyl problem, and it was repeatedly discussed at the highest State and Government levels.

Economic assistance was provided to the affected areas. Thus, the Russian President's decree "Special regime for privatization of enterprises in the Bryansk region" was issued on 30 November 1992. It authorized privatization of the region's enterprises located in the radiation contaminated areas through the transfer of their assets without compensation to the ownership of workers' collectives. The Russian Government's decree of 8 December 1992 "Measures for stabilization of the economic and social situation in the Bryansk region" provided for preferential credits and funds for maintenance of rural social facilities and authorized the use for social protection of the region's population affected by the Chernobyl disaster of 30% of the export duties collected on goods produced in the region's enterprises.

The Presidium of the Russian Federation's Supreme Soviet by its decision of 22 April 1993 established 26 April — the day the disaster happened at Chernobyl—as the Remembrance Day for the victims of radiation accidents and disasters. Every year a condolence meeting and a service is held at the Mitino cemetery in Moscow, where the Chernobyl heroes who died as a result of the accident are buried.

In recent years the interest of the higher Federal authorities in the Chernobyl problem has lessened, although the Federal structures became somewhat more active at the end of 1995 and the beginning of 1996 in connection with the preparations for the tenth anniversary of the disaster.

3.2. Description and development of legislation after the Chernobyl disaster

The Russian Soviet Federative Socialist Republic's (RSFSR) law "Social protection of citizens affected by radiation as a result of the disaster at the Chernobyl nuclear power plant" was adopted on 15 May 1991 (three days after the adoption of a similar USSR law) (RSFSR Law, 1991, 1992, 1995). Subsequently, amendments and additions were made to this law on 18 June 1992 and 24 November 1995. The purpose of the law is to protect the rights and interests of the citizens of the RSFSR (now the Russian Federation) who were exposed to unfavourable consequences as a result of the Chernobyl disaster or who were involved in the clean-up operations. The State guarantees the citizens of the Russian Federation compensation (and benefits) provided for under the above law for damage caused to their health and property by the accident and also for the risk of radiation damage as a result of residence and work in the area contaminated by radiation in excess of the permissible levels.

The law is based on the scientific concept of residence of the population in the areas affected by the Chernobyl disaster. It defines the regime and ecological improvement of the areas affected by radiation, the status of citizens affected by radiation and provides for pensions and compensation to citizens for the damage to their health resulting from the Chernobyl disaster. In addition, the law lays down the rights of enterprises, institutions, organizations and public associations in connection with the Chernobyl disaster; it provides for monitoring compliance with and penalties in case of violation of the Chernobyl laws.

Under this law the following zones have been established in the contaminated areas: exclusion zone, evacuation zone, zone of habitation with the right to resettlement and zone of habitation with preferential socio-economic status, and 12 categories of citizens affected by radiation resulting from the disaster have been defined. Depending on the zone of residence and the status of the citizens affected by radiation, the law has laid down compensations and benefits, measures for social protection, health care and pensions.

It was necessary to issue a large number of additional regulations in order to give effect to the provisions of the law. The abundance of such regulations in certain cases gives rise to ambiguous interpretation of the requirements set forth in the law and complicates the work of the local authorities. There are also direct contradictions. Under the Chernobyl law many categories of citizens are exempt from income and other taxes, while under the Russian Federation law on "Income tax from physical persons" these citizens are partly or fully liable to pay this tax.

The Federal executive and legislative authorities are adopting different approaches to the further development and improvement of the law. The amendments and additions to the law in 1995 were returned by the President of the Russian Federation for further revision, and he was compelled to sign the relevant law on 24 November 1995 after it had been passed for the second time by the State Duma and approved by the Council of the Federation by a two-thirds majority.

3.3. Description of the administrative structure and responsibilities at the local, regional and national levels

The RSFSR State Committee on the Elimination of the Consequences of the Chernobyl Accident was set up in the Russian Federation in 1990. The RSFSR State Committee on Social Protection of the Citizens and Rehabilitation of the Areas Affected by the Chernobyl and Other Radiation Disasters was formed in 1991. In January 1994 the Committee's functions were again transferred to the newly constituted Ministry of the Russian Federation for Civil Defence, Emergencies and Mitigation of the Consequences of Natural Disasters. The Ministry includes a Department for Eliminating the Consequences of Radiation and Other Disasters, which at the Federal level supervises the work on mitigating the consequences of the Chernobyl disaster. It is under the charge of a Deputy Minister.

At the regional level, the administrations of the regions and republics have committees, directorates, divisions and working groups, which directly deal with Chernobyl problems in their areas. This work is under the charge of one of the deputies of the head of administration of the relevant constituent unit of the Russian Federation. In the administrative regions, cities and urban and rural settlements situated in the contaminated areas the work of mitigating the consequences of the disaster is supervised by one of the deputies of the head of administration of the region or town and, in the case of rural settlements, by the head of administration.

4. DEMOGRAPHIC PROBLEMS

4.1. Dynamics of growth and decline in population in the contaminated areas since 1986

The Chernobyl disaster mainly affected the central and the central/black earth regions of the Russian Federation. These areas display a historically evolved common type of population reproduction. Its main features over the preceding decades have been low birth rate, high mortality, especially in the rural areas, and natural growth mainly due to the demographic growth potential accumulated in the age structure. Depopulation and ageing was a real problem here even before the Chernobyl disaster. An important aspect of the type of reproduction is the high migrational activity of the population, which is characterized by considerable scales and intensity of movement of certain groups, above all the youth. The disaster area embraced the regions of settlement of Slavs with close migrational relations throughout history (including the territories of the Russian Federation, Ukraine and Belarus).

The disaster substantially influenced the whole mechanism of the migration streams which developed in these areas, their composition and directions, the motives for migration, the ratio of organized and spontaneous movements and the role of information as a factor for migration. These increased the role of such motives as preservation of health and life, need for adaptation to new forms of activity in basically altered environmental conditions, psychological fatigue and fear in the face of uncertainty of the situation.

The influence of such a strong factor "pushing" people out of the regions affected by radiation should in theory have manifested itself in the mass exodus of the population from a number of the most contaminated areas. However, the actual trends of migration indicate that the influence of this factor is more complex in nature and that it is interconnected with the amount of information available to the population, its evaluation of the information, the possibility of shifting to other regions, the socio-economic policy being implemented in the contaminated areas and the not always favourable socio-psychological attitude to the migrants on the part of the local population in the uncontaminated areas.

At the same time, the processes under consideration are influenced also by a number of other external factors. The decline in production and in the standard of living is conducive to maintaining high mobility and drain of the population from a number of northern and eastern regions of the Russian Federation to regions in the European part of the country, including the "Chernobyl regions". One of the most significant factors affecting the contemporary migrational situation in the Russian Federation is the disintegration of the former USSR, the economic crisis and the rise of nationalism in the former Soviet republics, which encourage the growing stream of immigrants to Russia.

Analysis of the data presented in Table VI shows that in the rural parts of the Bryansk, Kaluga, Orel and Tula regions affected by the Chernobyl disaster there was a clear trend of increased population outflow in the first year after the accident (1986) — by 4–6%, followed by a slowdown in the rate of outflow. Since 1992 there has been a sharp change in migration — a stable growth in population in the rural parts of these regions. The movement of the population in the most contaminated areas of the south-western districts in the Bryansk region indicates that the growth in migration here by a factor of more than two is greater than the coefficient of natural loss of the population (see Table VII) (Veselkova, 1995).

Thus, the new trends of migration seen at present represent the influence of two groups of factors — internal (social protection measures for the population under the law of the Russian Federation and a certain amount of adaptation of the population to activities in the contaminated areas) and external, which are reflected in a substantial decline in migration to other parts from the contaminated areas and factors conducive to a massive inflow into the districts under consideration from the northern and eastern districts of the Russian Federation, areas of national and military conflicts both within the Russian Federation and from the former USSR republics.

At the same time, considerable movements of population to radiation-contaminated areas may cause new complications in that more funds will be needed to finance the State programme on mitigating the consequences of the disaster and

TABLE VI. BALANCE OF MIGRATION OF THE RURAL POPULATION IN THE MOST SEVERELY CONTAMINATED REGIONS OF THE RUSSIAN FEDERATION (%)

Regions	1980	1985	1986	1988	1990	1991	1992	1993
Bryansk	−19.3	−20.4	−24.5	−12.7	−21.4	−4.1	12.5	17.1
Kaluga	−21.6	−9.7	−11.4	0.2	−1.0	−1.7	16.0	18.8
Orel	−14.5	−11.5	−15.8	3.9	2.3	2.8	20.7	21.9
Tula	−18.6	−6.7	−11.2	−4.9	−2.6	−1.1	17.6	15.6

TABLE VII. MOVEMENT OF THE POPULATION IN THE MOST HEAVILY CONTAMINATED AREAS OF THE SOUTH-WESTERN DISTRICTS OF BRYANSK REGION IN 1993

Districts	Natural growth rate (‰)			Migration rate (‰)		
	Overall birth rate	Overall death rate	Natural growth rate	Arrivals	Departures	Migration growth
For all districts	11.65	16.65	−4.0	47.6	37.9	9.7
includiing:						
Gordeevka	13.3	20.8	−7.5	43.3	36.4	6.9
Zlynka	13.4	20.0	−6.6	78.9	41.3	37.6
Klimovo	9.5	16.5	−7.0	80.5	54.3	26.2
Klintsovka	11.1	24.2	−11.1	47.3	39.7	9.4
Krasnogorsk	12.1	17.4	−5.3	49.5	43.2	6.3
Novozybkov	10.1	22.6	−12.5	70.8	56.3	14.5
Starodub	5.1	25.3	−20.2	29.1	26.1	3.0
Town of Klintsky	11.5	13.2	−1.7	24.4	27.5	−3.1
Town of Novozybkov	12.9	13.9	−1.0	44.8	34.0	10.8

there will be greater social tensions in these regions. In many respects, the flow of migrants to the contaminated regions was encouraged by the Russian Federation's law "Social protection of citizens affected by radiation as a result of the disaster at the Chernobyl nuclear power plant", which provides for substantial compensation and benefits for the resident population. However, the newly arrived migrants in the affected areas are exposed to the effects of radiation to a much lower extent than the population which has been residing there since the day of the accident and in whose case the exposure doses were received in 1986–1989, the most difficult years from the standpoint of radiation. Therefore, to the above law of the Russian Federation appropriate amendments were made on 24 November 1995, which differentiate payments of compensation to citizens, depending on the time of their residence in the radiation-contaminated areas or cancel payments in the case of new residents of zones where inhabitants have a preferential socio-economic status.

Of the factors determining the demographic phenomena, the more important are the age and sex composition of the population, the processes of urbanization (decline in the percentage of the rural population and increase in that of the urban population), the percentage of the able-bodied among the total population, especially the young able-bodied, and the rates of ageing of the population. In all the affected regions we note a tendency of decrease in the percentage of rural population and increase in the urban population, a decline in the rates of population growth and, in rural areas, a negative growth. There is a deterioration in the age structure of the able-bodied population; in rural areas persons in the pre-pension age groups constitute up to 35–40%. The ageing of the population, and especially its able-bodied part, poses new problems for society and the State, since it is necessary to develop an infrastructure for the aged and since this places an additional economic burden on the able-bodied population.

4.2. Dynamics of birth rate and mortality

The dynamics of birth rate and mortality in the contaminated areas in the regions affected by the Chernobyl disaster reflect the general Russian trends (except for the Tula region), although the loss of population in these regions has been more intensive in the last few years than the Russian average (see Table VIII).

In the most radiation-contaminated districts of the Bryansk region, where people live in areas with a radiation level above 15 Ci/km^2, the loss of population in 1994 was 8 per 1000 persons (5.1 per 1000 for Russia as a whole). The overall mortality index for these districts was 18.7 per 1000 — the highest for the last 10 years (14.5 per 1000 for Russia as a whole).

The index of mortality from diseases for the rural population of the radiation-contaminated areas in the Kaluga, Orel and Tula regions is higher than the Russian average. The mortality index for the rural population of the Bryansk region remains

TABLE VIII. OVERALL BIRTH, DEATH AND NATURAL GROWTH RATES OF THE POPULATION LIVING IN AREAS CONTAMINATED BY THE CHERNOBYL ACCIDENT OF REGIONS OF THE RUSSIAN FEDERATION (per 1000 inhabitants)

Area	Overall birth rate	Overall death rate	Natural growth rate
Russia			
1980	15.9	11.0	4.9
1986	17.2	10.4	6.8
1992	10.7	12.2	−1.5
1993	9.4	14.5	−5.1
1994	9.6	15.8	−6.0
Bryansk region			
1980	14.8	12.6	2.5
1986	16.6	11.3	5.3
1992	11.2	13.6	−2.4
1993	10.2	15.9	−5.7
1994	9.8	16.9	−7.1
Kaluga region			
1980	13.8	12.4	1.4
1986	14.7	11.5	3.2
1992	9.2	13.2	−4.0
1993	8.0	15.8	−7.8
1994	8.2	17.4	−9.2
Orel region			
1980	13.2	12.7	0.5
1986	14.1	11.8	2.3
1992	9.7	14.0	−4.3
1993	9.1	16.0	−6.8
1994	9.5	16.8	−7.3
Tula region			
1980	12.1	12.7	−0.5
1986	12.8	12.4	0.0
1992	8.2	15.8	−7.6
1993	7.6	18.4	−10.7
1994	7.6	20.5	−12.9

at the level of the Russian average, thanks to the greater attention paid to the clinical examination of the population in the districts affected by radiation, early detection and better treatment of diseases (see Table IX).

Infant mortality in the affected areas, as in Russia as a whole, is higher by a factor of about 2–3 than in the economically developed countries, and has increased in the last few years (see Table X). The growth in infant mortality in the last few years shows a strong dependence on the external conditions — economic, social and ecological — to which pregnant women react. There has been a rise in the morbidity of pregnant women in the Russian Federation. In 1993 only 40% of child births were without complications. Maternal mortality is not declining, it exceeds the European average by a factor of 2.5 (Veselkova, 1995).

A most important indicator of the demographic situation reflecting the trend of increased mortality and poorer quality of health is life expectancy at birth. The most unfavourable situation in the affected regions is encountered among the male

TABLE IX. MORTALITY FIGURES FOR THE MAIN CAUSES OF DEATH AMONG THE RURAL POPULATION OF CONTAMINATED AREAS OF THE RUSSIAN FEDERATION (per 100 000 inhabitants)

Regions	Diseases of the blood circulation system	Neoplasms	Trauma	Respiratory diseases
Russia				
1989	658.1	170.5	162.3	87.8
1993	765.1	180.4	251.2	98.1
Bryansk region				
1989	661.5	153.3	154.0	73.9
1993	743.2	181.4	246.9	70.2
Kaluga region				
1989	74 468 [sic]	194.9	179.0	81.4
1993	102 467 [sic]	214.0	235.8	120.0
Orel region				
1989	664.6	160.7	185.8	110.3
1993	816.9	183.5	277.4	144.0
Tula region				
1989	710.0	196.5	218.7	120.8
1993	707.0	201.6	373.1	144.3

population of the rural areas, where life expectancy at birth in 1993 was shorter by 0.7–4.1 years than the Russian average (see Table XI).

TABLE X. INFANT MORTALITY IN THE AREAS CONTAMINATED BY THE CHERNOBYL ACCIDENT OF REGIONS OF THE RUSSIAN FEDERATION (per 1000 births)

Regions	1980	1985	1991	1992	1993	1994
Russia	22.1	20.7	17.4	18.0	19.8	18.7
Bryansk region	18.9	18.4	17.2	17.1	19.6	17.9
Kaluga region	19.4	18.7	16.6	17.5	16.2	17.5
Orel region	20.0	19.5	15.7	14.7	16.9	17.2
Tula region	23.9	23.7	17.0	15.5	21.2	19.8

TABLE XI. LIFE EXPECTANCY AT BIRTH (YEARS) OF THE RURAL POPULATION IN THE REGIONS OF THE RUSSIAN FEDERATION MOST HEAVILY CONTAMINATED BY THE CHERNOBYL ACCIDENT

Regions	Rural population				
	1985	1987	Increase over the period 1985–1987	1993	Decrease over the period 1987–1993
Russia					
Men	59.8	63.2	3.4	59.7	5.3
Women	72.6	74.4	1.8	71.5	2.9
Bryansk region					
Men	58.4	61.2	2.8	56.5	5.1
Women	72.3	74.5	2.2	70.2	4.3
Kaluga region					
Men	58.4	61.2	2.8	56.5	5.1
Women	72.3	74.5	2.2	70.2	4.3
Orel region					
Men	58.5	61.1	2.6	56.8	4.3
Women	73.1	74.5	1.4	72.3	2.2
Tula region					
Men	55.9	59.5	3.6	53.8	5.7
Women	72.0	72.9	0.9	69.7	3.2

5. DEVELOPMENT OF THE ECONOMY IN THE CONTAMINATED AREAS

5.1. Special problems arising from the accident

Thanks to the measures taken by the State, the socio-economic situation in the affected areas in the post-accident period has been distinguished by a certain stability. It was possible to compensate the enterprises and collective farms for the material losses associated with the exclusion of a part of the areas, the cessation or re-profiling of agricultural activity and other consequences of the accident through supplies of additional equipment, material resources and mineral fertilizers in larger quantities. The previous level of well-being of the affected population was maintained by a better supply of foodstuffs at State prices, durable consumer goods, medicines and also through payment of compensatory monetary grants, free maintenance of children in pre-school institutions and feeding of school children. Subsequently, especially starting in 1992, as a result of the adverse effects of the socio-economic processes occurring in the Russian Federation, the situation started to deteriorate sharply in the affected areas, which are characterized at present by low economic performance of the industrial and agricultural enterprises, joint-stock companies, various kinds of collective co-operative farms and individual commodity producers and a lower standard of living than in the non-contaminated regions.

The economic activity in these areas is regulated at present by the Federal law on social protection of citizens affected by the Chernobyl accident and the Russian Government's decree No. 1008 of 25 December 1992 "Regime for areas affected by radioactive contamination as a result of the disaster at the Chernobyl nuclear power plant". Depending on the radioactive contamination level in the areas, the regimes for their economic use have been defined:

(1) Zone of habitation with preferential socio-economic status (1–5 Ci/km^2). Economic activities may be pursued without any restrictions.

(2) Zone of habitation with the right to resettlement (5–15 Ci/km^2). Economic activities may be pursued virtually without any restrictions only with monitoring of the status and improvement of the environment.

(3) Zone of evacuation (15–40 Ci/km^2). Economic activities may be pursued in accordance with the results of radioecological monitoring, and agricultural land may be used on the basis of scientific recommendations. For this zone as a whole, a system of restrictions has been established for the use of nature with a view to bringing the contaminated areas to a state suitable for economic use and activity of the population and to rehabilitating these areas gradually for economic activities.

(4) Exclusion zone (above 40 Ci/km^2). A system for utilization of nature has been introduced, which forbids all types of forest utilization, agriculture,

production and processing of minerals and passage of all types of transport. No economic activity is permitted.

The radiation-contaminated areas exhibit especially sharply the general features of the economic and ecological crisis in the Russian Federation. These include decline in production, movement of the intelligentsia out of those areas, collapse of the consumer sector, inadequate communal and service facilities and medical care. This is especially typical of the evacuation zone, where 90 800 persons are living at present, and the zone whose inhabitants are entitled to be resettled (347 000 persons).

The economy of the contaminated areas is part of the country's economy and should naturally be restructured and converted into a market economy. But at the same time it is necessary in these areas to apply special measures on improving the environment and social protection of the population, which require centralized State intervention at all its levels. This problem cannot be resolved in isolation from the general problems of socio-economic development of the country and its regions under the conditions of transition to a socially oriented market and no less acute theoretical and practical problems of Russia's getting out of the crisis. In the contaminated areas the role of the middle class — the main bearer of market relations — is still comparatively small, and there is a rise in the crime rate and alcoholism is widespread. While in 1995 the rise in crime (number of recorded crimes) on average for Russia was 5%, during the same period it was 5% in the Tula region, 13% in the Bryansk region and 21% in the Kaluga region.

The regions most affected by a number of the "Chernobyl" and other economic causes are the subsidized areas. The transfers (subsidies from the Federal budget), apart from Federal programmes, to the budget receipts of these regions during 1994 constituted 20.1% for the Bryansk region, 15% for the Kaluga region, 3.6% for the Orel region and 9.7% for the Tula region.

With Russia's transition to market economy there has appeared a new problem — unemployment. First of all, it started appearing in the weak, depressed regions or in regions weakened by such unfavourable events as the Chernobyl disaster. The level of unemployment in the Kaluga, Orel and Tula regions rose at rates close to the Russian average but in the Tula region it has been well above (by a factor of 1.5) that since 1994 (Table XII). In this region the number of registered unemployed per vacancy is among the highest — 30.5 in 1995, as compared to the Russian average of 7.1.

The level of unemployment in the affected regions is still being contained by the existing provision of the law on compensation payments to the working population calculated on the basis of the minimum salaries (from 0.8 to 4 minimum salaries per month, regardless of the employee's nominal salary). Under these conditions, attempts are made locally to have at least some kind of job for the population and often compensation payments and benefits are considerably higher than the nominal salary.

TABLE XII. UNEMPLOYMENT LEVELS IN THE REGIONS OF THE RUSSIAN FEDERATION MOST HEAVILY CONTAMINATED BY THE CHERNOBYL ACCIDENT

Regions	On 1 January 1992	On 1 January 1993	On 1 January 1994	On 1 January 1995	On 1 January 1996
Russian Federation	0.08	0.7	1.0	2.0	2.7
Bryansk	0.0	0.8	1.6	3.7	4.7
Kaluga	0.01	0.4	0.7	1.8	2.5
Orel	0.11	0.4	0.9	3.6	2.1
Tula	0.01	0.4	0.5	0.9	1.7

The unemployment level is calculated as the ratio of people registered with the employment office to the total working population.

5.2. Possible development of activities to restore the economy

In the post-Soviet period, work to restore the economy of the affected areas and to protect the population has been proceeding in accordance with the "Unified State Programme for the Protection of the Population of the Russian Federation from the Effects of the Chernobyl Accident for the Years 1992–1995 and up to 2000". The aim of the Programme is to reduce the negative medical, social and psychological effects of the accident to the lowest possible level, to create a social protection system for citizens, and to bring about the ecological and economic rehabilitation of the contaminated areas.

In addition to this Programme, in view of the particular importance of protecting children who have been affected by the unfavourable consequences of the accident, a federal programme entitled "Children of Chernobyl" has been adopted. Since 1993, this programme has been incorporated into the more general programme "Children of Russia" which has been designated a Presidential programme. The aim of the "Children of Chernobyl" programme is to reduce the effect of negative factors from the Chernobyl accident on the health of children, to ensure their medical and psychological rehabilitation, and social and legal protection, and to maintain the health of pregnant women and provide assistance to breast-feeding mothers in regions which have been subjected to radioactive contamination.

In 1995, the federal special programme on the provision of living accommodation for Chernobyl nuclear power plant accident cleanup staff for the period 1995–1997 ("Houses for the Cleanup Staff" programme) was adopted and began to be implemented; under this programme, it is planned to build 27 800 flats over this period in all those parts of the Russian Federation where these people live. These flats will be mainly for invalided cleanup staff, and for the families of invalids who have died. In 1995, work was started in practically all the constituent parts of the Russian Federation and the first few hundred flats have already been turned over to invalided cleanup staff.

While implementing these programmes, we have developed experience in the rehabilitation of areas affected by accidents and have conducted intensive research into new means of enhancing the efficient utilization of the resources allocated by the State. By social and economic rehabilitation of regions affected by man-made accidents, we understand a complex of social, economic and ecological measures aimed at social protection of the public and rehabilitation of the environment by restoring and further developing the economies of these regions. The rehabilitation work is aimed at the population, enterprises and the environment. In a broad sense, the final aim of this rehabilitation work in affected areas is to bring living conditions and the standard of living of the population up to the average level throughout the various parts of the country (regions, republics), and then up to the scientifically established standards accepted in the country (Voznyak, 1993).

Alongside the social development of the affected areas, we plan to create an economic structure there which will ensure the profitable functioning of the agro-industrial sector which provides the population with good quality food products (the contaminated regions are mainly agricultural areas); we also plan to compensate the affected regions for the economic damage caused by the Chernobyl accident by assigning the resources and investment required to bring about the economic resurgence of these regions, bringing the economic potential up to par and enhancing the quality of life of the population.

During the course of the Chernobyl programme, the investment projects planned under it were either totally or partially implemented. Over the period 1992–1995, 1.3 million m^3 of living accommodation, schools, hospitals, polyclinics (see Table XIII) and communal facilities were built in the affected areas of the Russian Federation and for evacuees; thousands of kilometres of roads and gas pipelines were built, and a series of production facilities (mostly small-scale) for processing agricultural produce, all of which has facilitated the economic resurgence of the affected regions (On the Implementation of the State Programme 1992, 1993, 1994 and 1995). The Chernobyl investment projects which are being implemented in affected regions were in the majority during these years and, sometimes, practically the only projects which were being implemented. If we consider that the specific proportion of the overall volume of capital investment which is financed from the federal budget was 11.9% on average in the Russian Federation in 1995, in the Bryansk region it was 36.4%, in the Kaluga region it was 18.2%, in the Orlov region it was 13.8% and in the Tula region it was 22%.

TABLE XIII. NEW HOUSING, SOCIAL AND CULTURAL FACILITIES IN THE "CHERNOBYL ZONE" OF THE RUSSIAN FEDERATION FROM 1992 TO 1995

	1992	1993	1994	1995	1992–1995
1. Housing (1000 m^2)	649	299	242[a]	1161[a]	1 306
2. Hospital (beds)	415	180	891[a]	518[a]	2 004
3. Out-patients' clinics (visits/working day)	2595	1735	605[a]	1906[a]	6 841
4. Schools (places)	9243	2814	2796[a]	3231	18 084
5. Pre-school facilities (places)	1330	775	500	310	2 915
6. Clubs and cultural centres (places)	1200	1100	1200	—	3 500

[a] Taking into account the "Children of Chernobyl" programme.

The material and technical infrastructure of the health services has been significantly reinforced, the manufacture of agricultural machines with special hermetic cabins equipped with filtered ventilation and air conditioners has been organized for the affected regions, and the issue of food products with various vitamin and food additives which increase the resistance of the human metabolism to radiation effects and facilitate the elimination of radionuclides from the metabolism has been initiated.

To increase the economic efficiency of the rehabilitation measures which are being implemented pursuant to decree No. 383 of the Government of the Russian Federation of 23 April 1994 entitled "On the Measures to Stabilize the Social and Economic Situation in the Kaluga Region", a programme has been prepared with a view to carrying out an economic experiment in this region called "The Kaluga priority" (in five contaminated areas of the region); under this programme, it is planned to organize a transition from free budgetary financing to the offering of investment and tax loans for the social, economic and ecological rehabilitation of these regions, the aim being to increase the level of interest of enterprises and the population in these contaminated areas in the restoration process and the accelerated cleanup of the accident.

The implementation period for all the Chernobyl programmes has been extended to 1998 and there is a commitment to develop them up until the year 2000.

6. LIVING CONDITIONS IN CONTAMINATED AREAS

The consequences of the Chernobyl accident, combined with the economic and social changes which have taken place in the Russian Federation in recent years, have led to a reduction in the capacity of the population to adapt to these changing circumstances, an impairment of quality of life, and a change in social functioning. The situation has also been complicated by the dissemination and distortion of information on the consequences of the accident and the measures being taken to remedy them. Sociological research carried out in these areas reveal a striking tendency in the behaviour of the population: despite the complex ecological situation, the inhabitants in the affected areas react primarily to the economic crisis, food shortages and the inflation level. The difficult material situation seems more threatening to them than the negative effect on their health of the unfavourable radiation situation.

Chief characteristics of the standard of living: Income and salaries in the areas affected by the Chernobyl accident are significantly lower (60–72%) than the average for the Russian Federation, and the rate of their decline in 1995 was significantly lower than the average Russian levels for the Bryansk, Kaluga and Orlov regions (see Table XIV). Despite the material and technical development of the social infrastructure in these regions, the total amount of living accommodation, hospitals, outpatient polyclinics, and preschool facilities available to the population there is mostly lower than the averages for the regions and for the Russian Federation; and, in certain

TABLE XIV. MONETARY INCOME OF THE POPULATION IN THE REGIONS MOST HEAVILY CONTAMINATED BY THE CHERNOBYL ACCIDENT OVER 9 MONTHS (JANUARY-SEPTEMBER) IN 1995

Regions	Average per capital monetary income (per month, 1000 of roubles)	Average monthly salary (1000 of roubles)	As % of 9-month period in 1994	
			Real monetary income	Real salary
Russian Federation	475.3	429.7	88	71
Bryansk region	307.6	256.7	73	65
Kaluga region	389.7	303.1	87	65
Orel region	365.5	251.6	79	62
Tula region	397.4	321.7	88	75

cases, it has not increased for four years and has even decreased owing to the closure of institutions of this kind which were housed in dilapidated and suitable [sic] buildings (see Table XV).

State of health of the population: An increase in the incidence of disorders of the endocrine system, the blood and the haemopoietic organs, the circulatory system, ischaemia, diabetes and stomach ulcers has been found in the population in the contaminated areas, as have signs of immune suppression. Alongside the somatic disorders, there is an observable steady increase in illnesses related to psychic disorders.

There is an observable increase in general and primary morbidity in children — in the contaminated areas it is higher than the average for the Russian Federation — including diseases of the endocrine system, blood diseases, congenital development anomalies, and disorders of the digestive organs. Chronic diseases are on the increase. If we consider that the number of children registered as receiving medical attention in the last seven years has increased on average in the Russian Federation by 17.5% (100 000 children), in the Bryansk region it has increased by 39% and in the Kaluga region by 37%. In particular, there is a sharp increase in endocrine pathology in children (from 1988 to 1994, the total increase in this form of disease amounted to 75% in the Russian Federation, whereas it was 312% in the Bryansk region and 566% in the Orlov region); many cases of cancer of the thyroid gland have been found in children and adolescents who were children at the time of the Chernobyl accident (62 cases by the end of 1995).

TABLE XV. INDICES FOR THE REGIONS OF THE RUSSIAN FEDERATION MOST SEVERELY AFFECTED BY THE CHERNOBYL ACCIDENT FOR THE PERIOD 1990–1994

	Russia		Bryansk region				Kaluga region			
			Average regional		Radioactively contaminated districts		Average regional		Radioactively contaminated districts	
	1990	1994	1990	1994	1990	1994	1990	1994	1990	1994
Total housing area (m^2 per inhabitant)	16.4	17.4	17.6	18.8	17.5	17.9	16	17.5	17.6	19.3
Hospitals (beds per 10 000 inhabitants)	137.5	129.7	140.9	127.4	143.5	129.3	133.8	123.9	134	125
Out-patients clinics (visits per working day per 10 000 inhabitants)	217.4	228.7	174.2	182.6	173	178.5	159.6	156.7	157.3	169.3
Pre-school facilities (as a percentage of the number of children of the corresponding age)	66.4	56.6	62.6	53.9	67.5	60.8	59.7	55.7	55.5	62.8

TABLE XV. (cont.)

	Orel region				Tula region			
	Average regional		Radioactively contaminated districts		Average regional		Radioactively contaminated districts	
	1990	1994	1990	1994	1990	1994	1990	1994
Total housing area (m^2 per inhabitant)	17.7	18.6	17.5	18.1	18.4	19.1	17.9	18.6
Hospitals (beds per 10 000 inhabitants)	141.7	130.8	140.3	130.5	147.1	145.3	139.9	137.9
Outpatients clinics (visits per working day per 10 000 inhabitants)	170.3	176.3	167.3	176.8	195	209.9	183	188
Pre-school facilities (as a percentage of the number of children of the corresponding age)	57.5	50.4	62.7	50.7	66.3	60.9	64.6	66.4

Social and psychological consequences of the accident: Research carried out over the whole post-accident period, and in particular in recent years, has put us in a position to be able to evaluate dynamically the social and psychological consequences of the Chernobyl accident which are manifesting themselves principally in mass psychological reactions which are related to a number of accident and post-accident factors: increase in anxiety, health worries, deterioration in social functioning, increase in the number of functional psychosomatic syndromes. Over this period, there has been a change in the various parameters of the quality of life for whole groups of the population involved in the accident. Over 70% of the inhabitants of contaminated areas and the cleanup staff report their health as bad or very bad, which does not entirely correspond to the objective medical facts. At the same time, people are inclined to attribute all problems which relate to their impaired sense of well-being to the accident or its consequences. All other factors of everyday life which usually cause health problems are pushed into the background or ignored. This is one of the striking forms of dysadaptive social reaction.

In contrast to all other natural or man-made catastrophes, the psychological distress after a radiation accident does not dissipate with time but is like a smouldering volcano which is always ready to break out again when combined with recurrent stress factors which remind the subject of the initial trauma — the accident. This additional stress factor may be provided by such things as the countermeasures, the economic difficulties, the appearance of long-term medical consequences, features of post-accident legislation. Information about the accident, its consequences, and the measures which are being taken to eliminate them reaches people principally through the mass media. Unreliable and contradictory information creates "cognitive dissonance" which further worsens the stress reactions and encourages mistrust of the authorities at all levels; this makes management of the post-accident situation difficult.

Work is being carried out with a view to socially and psychologically rehabilitating the affected members of the public; this means enhancing the capabilities of the population to adapt to changes in their living conditions, their ability to deal with problems, to develop their capacities for self-expression, and to accept responsibility for their lot in life. To this end, social and psychological rehabilitation centres are being set up. These centres, which are being organized jointly with UNESCO, are operating in the most seriously affected regions: Bryansk, Tula and Orlov. They are also being set up in other areas.

The principal activities of these centres are individual and family consultation sessions, group therapy, support groups, discussion groups, interest-related groups; there are information meetings, leisure activities, work in a play room with children and adolescents. Over the past year in which these centres have been operating, over 35 000 people have visited them which, taking into account the various centres and categories of the public (children, adolescents, adults), constitutes between 6 and 53% of the population served.

Those who are regularly attending the centres are exhibiting a clear reduction in their level of depression and disruptions in social functioning; they are becoming more active and communicable. The specialists at these centres have recorded cases of prevention of the development of more serious stress disorders among the population. In conclusion, the relatively limited operational experience of these centres, and sociological research carried out among members of the public who both use and do not use their services, confirm the steady realization of one of the main aims of these institutions — a reduction in psychological distress among the public which has a positive impact on their health, their ability to work, their initiative, and their self-confidence when solving problems which arise.

7. REVIEW

Current thinking and activities in connection with the efforts to re-establish the social conditions of the inhabitants of the contaminated areas, migrants and the liquidators:

- Fundamental social and economic measures to deal with the consequences of the Chernobyl disaster have been formulated and consolidated into three Chernobyl programmes (the Unified Programme ... , Children of Chernobyl, Housing for Liquidators). The funds needed to implement them are being set aside as part of the Russian Federation's federal budget for the coming year. Reductions in the levels of resources allocated and their diminished share of GDP and the State budget are adversely affecting attempts to restore the socio-economic well-being of the affected population;
- Major consideration must be given to monitoring the health status of the affected population, and if necessary to providing them with treatment and conditions for recovery in sanatoria and health resorts. This is being achieved by means of a Law and through the allocation of high-priority funds for these purposes in annual budgets;
- The socio-psychological consequences include the non-radiological risks arising from the radiation accident, and their impact must be given as much consideration as the impact of the dose received by the population, since psychological distress is contributing not only to population morbidity, especially psychosomatic illnesses, but also to mortality levels;
- Public awareness must be strengthened through the provision of objective, up-to-date information on the public hygiene situation, dose levels, the risk from delayed consequences, and other ecological and socio-economic considerations;
- Now that the resettlement of the inhabitants of contaminated areas is almost complete, the members of the public who were moved first must be given well-planned housing at their place of residence (if they require it). In order

to solve these problems, the administrative bodies in the areas of the Russian Federation where migrants are living are being allocated funding out of the annual budget.

The lessons of past experience and the direction of future activities:

— The required action must be implemented on a national scale, so that all scientific, logistical, normative, medical, legal and institutional arrangements are in hand in case of further Chernobyl-type disasters;
— The experience of dealing with the consequences of the Chernobyl disaster over a ten-year period must be studied carefully and incorporated into a special approved document to provide guidelines for use in eliminating the unsatisfactory aspects of current activities and in determining the future course of the work done with members of the public affected by the accident;
— Everything feasible must be done to improve the demographic situation in the areas hit by the disaster — if not, the decline in the reproduction rates of their populations may become irreversible in the near future;
— Following the adoption of the new "Plan on radiation, medical and social protection and rehabilitation of the population of the Russian Federation which suffered exposure as a result of the accident", it will be necessary in the near future for the Russian Federation to change over to a new system of classifying the contaminated areas (on the basis of dose burden to the population). This will reduce the size of area and the number of its inhabitants, and allow financial and material resources to be concentrated on the provision of specific social protection arrangements for liquidators and migrants, and for members of the public living in the most difficult radiation situations;
— In order to increase the effectiveness of the measures being carried out, the commercial component of the socio-economic and ecological rehabilitation of the affected areas must be improved, and a system must be established which ensures that organizations engaged in economic activity and members of the public have a financial interest in accelerating the work to deal with the consequences of the disaster and raising the output from the resources invested in the rehabilitation measures. As an experiment, an economic programme known as the "Kaluga priority" has been set up (in five affected areas of Kaluga region), which provides for a transition from free fiscal subsidies to a system which ensures that resources granted by the Government (investment and tax credits) are recovered out of internal sources of accumulation and as the result of the increased effectiveness of investment projects and commercial undertakings carried out in the contaminated areas;
— The introduction of further activities in the area of the Chernobyl trace will depend on the socio-economic situation of the country and the Government's social policy, and will be considered in the context of the forecast and programme of socio-economic development in the Russian Federation for the

years 1996–2000, the forecast and plan of socio-economic development in the Russian Federation for the years 1996–2005, which are currently being prepared by the Government of the Russian Federation, and also in the light of the Plan for the Russian Federation's transition to sustainable development.

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Report for Belarus

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1. INTRODUCTION

For ten years the Republic of Belarus has been living under conditions of large-scale radionuclide contamination caused by the explosion of a nuclear reactor at the Chernobyl nuclear power plant on 26 April 1986. It was the most powerful disaster of its kind anywhere on the planet. The radiation released affected practically the entire northern hemisphere. The most highly radioactive trace left by the accident was on Belarus territory. Scientists are still arguing about the quantity of radionuclides released into the atmosphere as a result of the nuclear reactor explosion. The most conservative estimates compare it to the effect of at least 10 atom bombs exploding.

The consequences of the Chernobyl accident have had a serious effect on all — including social, economic and political — aspects of life in the afflicted regions and in Belarus as a whole, and have been an extremely destructive factor. The entire Republic suffered in the immediate post-accident period from radionuclide releases, including short-lived radionuclides.

2. DESCRIPTION OF THE SITUATION IN BELARUS AFTER THE CHERNOBYL ACCIDENT

2.1. Radioecological situation

A total area of 46.45 thousand km^2, or 23% of the entire area of Belarus, was contaminated with radionuclides as a result of the Chernobyl accident. 45% of this area has a caesium-137 contamination level exceeding 1480 kBq/m^2, 8.9% has a contamination level between 555 and 1480 kBq/m^2, 21.3% a level between 185 and 555 kBq/m^2, and 65.3% a level between 37 and 185 kBq/m^2. There are 27 towns and more than 3600 other settlements situated in contaminated areas.

The regions most severely affected by contamination as a result of the disaster were Gomel, Mogilev and Brest, although other regions of Belarus have also been contaminated to a greater or lesser degree. Radioactive contamination of the area is extremely uneven and has a ''spot-like'' character. Thus, in Kolyban' in the Bragin area of the Gomel region, caesium-137 contamination fluctuates from 170 to 2400 kBq/m^2.

Maximum contamination levels are found in the evacuation zone (caesium-137 — 59 200 kBq/m^2, strontium-90 — 600 kBq/m^2, plutonium-239,-240 — 150 kBq/m^2). Anomalously high contamination levels are also found outside the zone at a distance of 150 km from the Chernobyl nuclear power plant (Shepetovichi, Gomel region — 2271 kBq/m^2, Chudyany, Mogilev region — 5402 kBq/m^2).

Strontium-90 contamination of the Republic has a local character. Soil contamination levels greater than 5.5 kBq/m^2 have been discovered in an area measuring 21.1 thousand km^2, that is 10% of the Republic's total area. The maximum quantity of strontium-90 in the soil of the closest zone is found inside the 30 km zone of the Chernobyl nuclear power plant and reaches 1800 kBq/m^2 in the Khojnik area of the Gomel region. The highest strontium-90 content in soils of the furthest zone are found at a distance of 250 km in the Cherikov area of the Mogilev region (29 kBq/m^2) and also in the Vetkov area in the northern part of the Gomel region (1370 kBq/m^2).

Plutonium-239,240 contamination of the soil above 0.37 kBq/m^2 encompasses an area of approximately 4.0 thousand km^2, that is about 2% of the area of the Republic. These areas, where the predominating plutonium contamination levels range from 0.37 to 3.7 kBq/m^2, are found in the Bragin, Narovlyan, Khojnik, Rechitsa, Dobrush and Loev areas of the Gomel region.

18 000 km^2 of agricultural land belonging to 729 farms have been contaminated (22%) and 2.64 thousand km^2 of agricultural land and 1.9 thousand km^2 of forest have been withdrawn from agricultural use. About half of this forest is part of the Polesskij State Radioecological Reservation. As a result of the high long-lived radionuclide contamination density this land has to all intents and purposes been taken out of use forever. This so-called ''plutonium'' reservation is located in the centre of Europe.

A considerable quantity of radionuclides is found in the sediments of open and closed reservoirs. Caesium-137, strontium-90 concentrations have increased in ground and surface water. Caesium-137 and plutonium-239,240 contamination of the atmosphere exceeds pre-accident levels by an order of one or more, even in towns located in clean areas such as Minsk.

Two million two hundred thousand people, including 600 000 children and juveniles, have been subjected to the prolonged impact of long-lived radionuclides. 24.7 thousand people were evacuated from 107 villages in the Bragin, Narovlyan and Khojnik areas in the period immediately following the accident. Since the day of the accident, almost 131.2 thousand people have either been resettled in clean areas of the Republic or have left of their own accord. In all, 415 settlements in Belarus have been evacuated.

The resettlement of such a large number of people, as well as organization of basic living requirements in radionuclide-contaminated areas, meant that new settlements and jobs had to be created, enterprises and organizations underwent respecialization, a network of schools and kindergartens had to be developed, health care facilities set up, gas pipelines laid, new electricity transmission lines erected and much besides.

There are now 1 840 951 individuals, including 483 869 children and juveniles up to the age of 17, living in 3221 settlements in contaminated areas.

There were 109 817 individuals who took part in liquidating the consequences of the Chernobyl accident, including 2096 invalids, 35 211 individuals who participated in activities in the primary and secondary resettlement zone in 1986–1987 and in the evacuation zone in 1988–1989, as well as 72 252 individuals who participated in activities to liquidate the consequences of the accident in 1986-1987 in the evacuation zone.

An overall picture of people living in Belarus with various levels of radiation contamination, as at the beginning of 1996, is given in Table I.

2.2. Economic consequences

Since 1986 the Republic of Belarus has had to bear the enormous additional cost of mitigating the consequences of the Chernobyl accident. Up to 1991, however, the State programme for mitigating these consequences was financed from the USSR budget, i.e. the burden was carried by the entire Soviet Union. As of 1992, following the collapse of the USSR, the entire responsibility for financing the State programme fell on the shoulders of Belarus. Table II presents the dynamics of this expenditure.

Budgetary appropriations to deal with the consequences of the Chernobyl accident are concentrated in 5 main sectors. In 1995 these appropriations were distributed as follows (as a percentage of expenditure):

— Improving living conditions — 58.7;
— Resettlement — 10.6;
— Compensation — 28;
— Health care — 2.0;
— Radioecological monitoring — 0.2.

TABLE I. NUMBER OF PEOPLE LIVING IN AREAS WITH VARIOUS CONTAMINATION LEVELS

	37–185 kBq/m^2	185–555 kBq/m^2	555–1480 kBq/m^2
Population numbers	1 485 193	314 193	41 282
Of which children up to the age of 17 years	395 309	78 721	9 821
Number of settlements	1 933	1 102	176

TABLE II. DYNAMICS OF ANNUAL BUDGET USED BY THE REPUBLIC OF BELARUS TO MITIGATE THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT
(10^9 roubles)

Indices	1992	1993	1994	1995	1996 (plan)
State budget	31.4	421	7 109.7	38 723	62 937.1
Republican budget	19.8	250.03	4 860.6	26 145	42 172.5
Chernobyl expenditure as a percentage of:	3.95	40.3	491.6	3 002	4 639.1
State budget	12.56	9.59	6.9	7.7	7.3
Republican budget	19.95	16.1	10.1	11.5	11.5
Chernobyl tax	2.48	28	318.8	3 142.9	3 547.92
Proportion	62.8	69.5	64.8	77.7	79.9

The Chernobyl accident has had an extremely destructive impact on the economic activity of the population in contaminated areas. Scientists have calculated that the economic damage to Belarus from the accident is equal to 32 pre-accident annual budgets or 235 billion (10^9) US dollars calculated over a 30-year recovery period.

Agricultural production suffered more than any other branch of the economy. Direct losses from the withdrawal of land from agricultural use alone amount to 15.2 billion dollars. The value of the associated loss in gross output from agricultural production is 10.3 billion dollars. The loss of basic production and working funds is estimated at 0.9 billion dollars. Direct production losses in private subsidiary small holdings is more than 400 million dollars.

The structure of the damage to Belarus as a result of the Chernobyl accident over the period 1986-2015 is as follows:

— Direct and indirect losses — 29.6 billion dollars. Loss in profit — 13.7 billion dollars;
— Additional expenditure associated with coping with the consequences of the accident — 191.7 billion dollars;
— Damage to forestry — 4 billion dollars. Of that, 3.5 billion dollars or 86.7% is attributable to direct losses from material forest components;
— The damage to the social sector is estimated to be 14.2 billion dollars, distributed among the main sectors as: housing — 7.1, education and culture — 0.87, health care — 4.4, trade and public catering — 1.8 billion dollars;

— Damage to the construction industry of Belarus is 2.7 billion dollars and to the transport and communications sector — 3.4 billion dollars.

2.3. Political consequences, legislative and administrative measures to minimize the consequences of the Chernobyl accident

The political consequences of the Chernobyl accident are organically intertwined with the far-reaching socio-economic transformation process taking place as a result of the breakup of the USSR and the acquisition by Belarus of political independence. The positive political changes include:

(a) The lifting of the information embargo with respect to the real scale of the Chernobyl accident and its consequences and with respect to the real threat to the population's health and way of life;
(b) The democratization of all aspects of public life, as a result of which the population has become socially and politically emancipated and has liberated itself from previous political and ideological dogmas and clichés;
(c) The rapidly growing tendency of increasingly large sections of the population to move away from paternalistic illusions and adopt a position of independent social action: during the past three years (1993–1995) the number of people that have moved away from paternalistic notions and now rely on their own social activity has increased from 41.6% to 54.5%, i.e. more than half of the population in the affected districts;
(d) The transition of nearly half of the adult population in these districts (47.5%) to a market-entrepreneurial way of thinking and acting.

Those questioned were concerned at the increase in crime (80.8%) and at the poor social protection provided for those suffering as a result of the accident (75%). A positive attitude was found 3.6, 2.4 and 2.2 times less often than a negative attitude towards the activities of the procurator's office, the activities of the militia and the activities of the judiciary respectively.

In such a situation, the degree of social atomization and estrangement of people from each other and from society increases. At the same time both horizontal conflicts (between family members, neighbours, colleagues, etc.) and vertical conflicts (with the authorities) become more pronounced. While 10% of respondents indicated that relationships with friends and acquaintances had deteriorated in recent years, leading to conflicts in 8.4% of cases, it was found that relations with representatives of the authorities had deteriorated in 23.9% of cases (i.e. 2.4 times more frequently) leading to conflicts in 15% of cases (i.e. 1.8 times more frequently). As a result, social tension is more pronounced in the radioactively contaminated districts than in the ecologically clean ones.

The Belarus law on the social protection of citizens affected by the Chernobyl accident adopted in February 1991 lays down the main principles, concepts and means for the protection of the rights and interests of citizens who took part in the cleanup operation of the Chernobyl accident and its consequences, of those who were resettled and moved to new homes from the radioactively contaminated area, and of those who continue to live in this area. This law establishes that the social protection measures, including entitlements, are based on the annual dose criteria and the level of radioactive contamination of the area.

The law on the legal status of areas contaminated by radiation as a result of the Chernobyl accident adopted in November 1991 identifies different zones: the exclusion zone immediately around the site of the Chernobyl nuclear power plant; the priority evacuation zone, with a density of caesium-137 contamination higher than 1480 kBq/m^2; the secondary evacuation zone (from 555 to 1480 kBq/m^2); and the zone which continues to be inhabited and where regular radiation monitoring is carried out and the permissible dose in addition to background radiation does not exceed 1 mSv per year (37–185 kBq/m^2). This division, which also takes into account contamination by strontium-90 and plutonium isotopes, corresponds to the concept adopted in the Republic regarding residence in the contaminated areas. It establishes the legal status of the contaminated districts and identifies measures for the reduction of the radiation impact on the population and ecological systems, the implementation of environmental rehabilitation and protection measures, and the rational use of the natural and economic potential of these areas. The law governs aspects of residence, and the carrying out of economic, scientific research and other activities in the radioactively contaminated areas, including the disposal of radioactive waste and radioactively contaminated material.

There is legislation defining the concepts of national radioecological disaster, radioactively contaminated areas, land presenting a radiation hazard, land excluded from economic use, land for limited economic use, etc.

Belarus has an orderly hierarchical organizational administrative structure, among the various links of which duties and responsibilities are distributed at the local, regional and national levels. Following a decree of the Supreme Soviet in 1991, a State Committee for Problems associated with the Consequences of the Chernobyl Accident was set up in Belarus. In 1994, this Committee was transformed into the Ministry for Emergency Situations and Protection of the Population from the Consequences of the Chernobyl Accident. Its main tasks in dealing with the consequences of the Chernobyl accident are the implementation of State policy in the area of protection of the population, co-ordination and monitoring of the activities of the ministries and other central administrative organs in the relevant areas at national level.

The administrative functions and associated duties and responsibilities for the implementation of measures to deal with the consequences of the Chernobyl accident at regional level are carried out by the departments for emergency situations and protection of the population from the consequences of a nuclear accident that are set up within the regional executive committees and headed by the deputy chairman of the regional executive committee.

A similar administrative structure in terms of its functions, duties and responsibilities, but functioning at the local level, exists within the district executive committees. This structure is headed by the deputy chairman of the district executive committee and organizes and monitors the implementation of all measures to deal with the consequences of the accident and the social protection of the population at the local district level.

2.4. The demographic situation

As a result of the accident the number of people living in the areas contaminated by radiation has declined considerably. Mainly because of evacuation and resettlement measures, 131 200 people have left the worst affected areas of Belarus in the decade since the disaster. The highest rate of population outflow was from the areas of first and second phase resettlement, where the "mechanical" flow rate for the inhabitants in the first five years after the accident (1986–1990) was 140.7%. In areas where the right to resettlement existed, the "mechanical" flow rate was over two times less, at 59.5% for the same period. Even in the areas less seriously affected by radioactive contamination, as a rule population outflow exceeded inflow. Here, the outflow rate was 34.5% for the years 1986–1990.

Over the next five years, the rate of population migration from areas affected by the disaster declined. Nevertheless, in 1995 the number of people living in the areas of initial resettlement was only 10% of its pre-accident level, the figure for the areas of second phase resettlement being 52%. In the districts of Gomel region contaminated by radionuclides the population declined to 19 000, and in Mogilev region to 13 200.

As a result of selective migration (those leaving are mainly young people with children, and women rather than men) the population profile is undergoing significant distortion. The proportion of older men is rising on account of the increased migration rate among young women with children aged up to 14 years. In the contaminated areas the proportion of children has decreased by 18%, and the proportion of pensioners has increased by 12%.

Consequently, the working population has shrunk by 16%, and the overall occupational structure has been severely weakened. Owing to migration to environmentally clean areas the numbers of graduate specialists and skilled workers have declined 12–14% in industry, construction, agriculture, health services, education and cultural life. The impoverishment of the population has increased — the proportion of those living on the poverty line is 67%, of whom 17% must be regarded as beggars.

All this means that in demographic terms the areas hit by the Chernobyl disaster are fading away. Only 8.1% of women aged up to 40 living in the radioactively contaminated areas express a willingness to increase their families, 74.8% are abandoning the idea of having children and 17.1% are not planning to do so. Explaining why they do not want to try to have more children, 36% of women said they do not believe that the child will be born healthy.

The most sensitive indicator of a society's social well-being is the birth/death ratio. The number of births in Belarus during the nine years after Chernobyl (including 1994) declined from 165 000 to 110 600, i.e. by 43%. In areas severely affected by radiation, the rate of decline in the birth rate is 4–5 times greater. Thus, in the Narovlyan and Bragin districts of Gomel region the number of births in the post-accident period fell by factors of 2.3 and 2.1 respectively. More dramatic is the death rate in these districts. In 1994 the negative mortality balance, calculated from the ratio of births to deaths per 1000 members of the population, was 1.9 in Belarus and 1.8 in Gomel region, while in the Narovlyan district it was 4.6 and in Bragin district 8.8.

2.5. Living conditions in the contaminated areas

The negative socio-economic consequences of the Chernobyl disaster are having an increasingly destructive effect on work, especially on working conditions and work content, labour efficiency and remuneration, and employment trends. The average salary in the agro-industrial complex in the most seriously contaminated areas is 36% lower on average than in areas with a similar environment and no contaminated land. For example, the average monthly salary for nine months in 1995 in contaminated districts, converted to US dollars, was: Bragin 30, Narovlyan 25, Khoinik 32.5 and Chechersk 29. In clean districts of Grodnensk and Minsk regions, the figures are: Grodnensk 54, Korelich 53, Kopyl'sk 38 and Nesvizh 38. The average shortfall in payment of allocation to cover salaries in the agriculture of Belarus is 15% of the total needed, while the figure for contaminated areas is 22%. Almost 53% of the inhabitants of contaminated areas interviewed since September 1995 have expressed concern about poor working conditions and the content of their work. In these areas, despite the fact that a large number of skilled workers have left, the unemployment rates are rising rapidly.

The population's state of health in the contaminated areas is in stable decline. Since 1985, morbidity associated with malignant neoplasms has risen by 32%, while the figures for diabetes and stomach ulcers are 12% and 28.2% respectively. Over this period the number of myocardial infarctions has increased by a factor of 3.1, and the number of cases of anaemia by a factor of 3. In the contaminated districts of the Republic an increase is evident in diseases such as tuberculosis, autoimmune thyroiditis and thyroid cancer in children. In the years before the accident, only isolated cases of thyroid cancer in children were recorded in Belarus, but from 1986 to 1995 it affected 424 children aged up to 14 and 82 juveniles under 17. Objective indicators of morbidity in a more acute form can be seen in the subjective perceptions of illness among individuals and groups in the population. Concern about their state of health was expressed by 55.5% of respondents in 1987, 67.8% in 1991 and 83.2%

in 1995. The majority of those interviewed said that the main factor in the decline of their health was radiation contamination of the place where they lived. While in the environmentally clean Vitebsk region 28.3% of respondents say that their health has declined as a result of radiation effect, in Gomel and Mogilevsk regions the figures are 66 and 68.5%. In highly contaminated areas the proportion of people expressing that point of view is far greater — in the Khoinik district of Gomel region the level is 85.2%, and in the Krasnopol district of Mogilevsk region 81.6% of those interviewed believe it to be true.

In radioactively contaminated areas, persistent radioecological stress affecting groups of people has developed among a considerable proportion of the population. It is characterized by a widespread sensation of anxiety, arising from having to live with radiation risk and the danger to people's health and lives. It first arose, and remains a persistent presence, in extensive areas of the territory where large groups of people are present. This stress has generated several types of adaptive syndromes:

(a) Increased somatization of fearful expectations (''escape into illness''), which characterizes 72% of those interviewed and increases with age, from 16.2% in the 17–20 age group to 78% among people over 50 (characteristic of 34.6% of men and 77.7% [of women]);

(b) Undervaluation of personal needs and acquiescence in the face of the extreme circumstances of life in a radioactively contaminated area, with the result that a person's active potential is transformed into the ''victim'' mentality: noted in 22% of respondents;

(c) A socio-psychological state of existence giving rise to unpleasant distressing feelings (found in 29% of those interviewed), which increases with age and is found twice as frequently in women as in men, and which reaches a level where the feelings of hopelessness engendered are psychologically depressing to the individual (from 3.7% in Chechersk district to 11.7% in Khoinik district, out of the total number of persons interviewed). The drop in industrial production levels caused by the severance of economic relations, inflation and slow rates of economic reform are exacerbated by the effect of the radiation factor. Factory re-specialization by means of joint investment and the establishment of joint enterprises with CIS countries has not progressed as it should. Devolution of the ownership of industrial enterprises mainly took the form of share issues, and there has been no significant improvement in the economic indicators for these companies. The prospects for further industrial growth in the contaminated areas will depend on finding investment to modernize equipment and rebuild infrastructure, and on attracting young professionals, especially engineers and highly skilled workers. In the past two years, not one university graduate has been willing to go and work in Bragin, Narovlyan, Khoinik and and Chechersk districts. The potential exists to develop forestry and the wood-working and cellulose paper industries in areas where soil contamination by caesium-137 is less than 185 kBq/m^2. The activities which must be given high priority for development are the furniture industry, and chemical and chemical-mechanical timber processing, as well as the processing of potatoes, rape and sugar beet. This will require considerable capital input, including investment from abroad.

3. DISCUSSION

In discussing the results, it should be noted that, following the accident, nearly 131 200 people were resettled from 396 settlements to clean districts of Belarus, including 84 300 people from the priority and secondary evacuation zones. For the resettled families, 58 100 houses and flats were built and made available.

The strategy for preserving the health of the population by evacuating it from districts with high radioactive contamination densities and providing the right of voluntary resettlement prevented an increase in the number of possible diseases caused by the various exposure doses. It is possible to establish that Belarus has passed the critical boundary which could have led to the development of serious radiation injuries in the majority of the population.

In order to guarantee the normal way of life of the population affected by the Chernobyl accident, schools providing general education, pre-school facilities, hospitals and out-patient clinics were built. Structural improvements were made to many existing facilities and many new facilities were built in the production and domestic sectors in rural areas. Improvements and decontamination measures were carried out at settlements, livestock farms, machinery yards, industrial and other facilities.

From 1990 to 1995, a series of measures was undertaken to improve the provision of medical care to the affected population and to develop the material and technical infrastructure for health protection in the radioactively contaminated regions of Belarus. Ultrasound diagnostic centres were opened in all the districts affected by the Chernobyl accident and cancer centres in 14 of them. The regional centres have immunological laboratories.

295 hospitals and clinics were built, with 4858 beds and 22 587 visits per working day. A network of specialized establishments was established: the Scientific Research Institute for Radiation Medicine with a clinic in Aksakovshchina and branches in Gomel, Mogilev and Vitebsk, the Belarus Specialized Clinic in Minsk, the Belarus Specialized Centre for Thyroid Cancer, the Department for Bone Marrow Transplants at the Ninth Minsk Municipal Hospital. The Mogilev Regional Diagnostic Centre and new buildings at the Gomel and Mogilev Oncological Clinics were opened. Construction is continuing on the treatment building of the Scientific

Research Institute for Radiation Medicine, a specialized clinic in Gomel, and the Belarus Children's Oncological Centre.

Clinical examinations and rehabilitation opportunities are provided each year for those living in radioactively contaminated areas.

A State register has been set up containing information on more than 220 000 people: liquidators, evacuated and resettled people as well as those living in the priority and secondary evacuation zones and children.

However, despite the measures taken, the statistical data of the treatment and prophylactic establishments in Belarus indicate an increase in general somatic diseases in the Gomel and Mogilev regions.

Among children, there has been an increase in the incidence of anaemia, and chronic diseases of the otorhinolaryngological and respiratory organs. Of special concern is the increase since 1990 of thyroid cancer, particularly in children. There were 424 registered cases of thyroid cancer in children and 82 in adolescents (data as of 1 January 1996), whereas in the decade prior to 1986 there were only 2.

Each year, about 30% of all the resources provided for the financing of the law on the social protection of citizens affected by the Chernobyl accident are spent on medical rehabilitation measures to protect the health of the population affected by the Chernobyl accident and to improve their immune system. On the basis of this law, the number of citizens enjoying the right to free rehabilitation each year is 614 000, including 526 000 children and adolescents.

In view of the reduced possibilities for rehabilitation in CIS countries, a policy was adopted of establishing an independent medical rehabilitation infrastructure, including year-round operation at existing rehabilitation centres, at those under construction and at those being rebuilt, and the provision of educational facilities at such centres.

The agricultural sector of Belarus was badly affected by the Chernobyl accident. More than 18 000 km^2 of agricultural land were contaminated (about 21%), including 4100 km^2 of land contaminated by radioactive strontium, of which 2650 km^2 were withdrawn from economic use.

One of the most effective protection measures is the application of high doses of phosphorous and potassium fertilizers. The annual requirements for additional fertilizer calculated on the basis of the active ingredient is 10 600 tonnes of phosphorous and 48 400 tonnes of potassium fertilizers. In order to reduce the incorporation of radiostrontium and radiocaesium in plant production, it is essential to ensure an optimum level of soil acidity and, to achieve this, it is necessary to lime 65 000 hectares of contaminated agricultural land each year.

The problem of obtaining clean production at subsidiary small-holdings continues to be an extremely urgent one. Here, up to 10% of milk samples are registered each year as being contaminated with caesium-137 above the acceptable levels. In seven districts of the Gomel region, settlements and dairy farms have been identified where the acceptable levels are also exceeded for strontium-90 content.

Owing to the deterioration in the social and economic situation, the inhabitants are eating more forest produce and river fish. The contamination levels of more than 30% of samples are higher than those acceptable for these products.

In the period 1991–1995 more than 150 public buildings and facilities have been cleaned up; a further 480 sites require decontamination (without taking into account private property).

Sites of social importance are given the first priority for decontamination, such as kindergartens, schools, medical and rehabilitation establishments, recreation areas and places frequented by crowds, food industry enterprises and other industrial sites, as well as local sites with anomalously high contamination levels in inhabited areas.

Decontamination and demolition of buildings creates approximately 26 000 tonnes of heavy waste per year requiring burial in specially constructed repositories which are in extremely short supply in Belarus.

The limited nature of Republican resources has meant that each construction project has had to be carefully scrutinized and its importance in ensuring normal living conditions and production cycles in contaminated areas has been the main factor taken into consideration when preparing annual construction plans.

The scale of the Chernobyl accident and its negative effect on all spheres of life in Belarus (where material damage amounts to 235 billion (10^9) US dollars) have meant that expenditure just on the highest priority measures to deal with the consequences is considerable.

Outgoings on programme implementation in 1991 were 16.8% of the State budget, in 1992 12.6%, in 1993 9.6%, in 1994 6.9% and in 1995 7.3%.

1.8 million people have remained in areas with a caesium-137 contamination level greater than 37 kBq/m^2, including 312.6 thousand individuals in high risk areas where the additional Chernobyl dose commitment exceeds 1 mSv per year. In addition, there are 42.3 thousand people living in the secondary resettlement areas.

The main aim of the State programme to deal with the consequences of the Chernobyl accident for 1996 is to implement the laws passed by the Republic of Belarus on social protection of citizens suffering from the accident at the Chernobyl nuclear power plant, and on the legal status of land radioactively contaminated as a result of the accident at the Chernobyl nuclear power plant. It gives priority to maintaining and improving the health protection of people living in contaminated areas. A corresponding expansion of the rehabilitation establishment base in Belarus is foreseen by means of building, reconstruction and respecialization in clean areas.

In the task of maintaining the health of the population living in radioactively contaminated areas and ensuring the availability of qualified medical help, priority is given to further development of a network of specialized medical-diagnostic establishments and equipping them with up-to-date medical equipment. Further comprehensive enquiry into the state of health of the affected population is foreseen using specialized field teams, the carrying out of specialized clinical examinations, and giving priority to supplying the population in affected areas with medicaments.

To obtain "clean" agricultural produce and reduce the collective internal dose to the individual it is planned to continue work on developing agrochemical, meliorative and other protective measures in the agro-industrial complex.

Decontamination is one of the measures used to reduce the external radiation dose. It is planned to carry out a series of decontamination projects taking into account up-to-date information on the radiation situation, to establish burial sites for decontamination waste, and to monitor existing radioactive burial sites. The next area of work is related to establishing living conditions for the population which are in line with radiation safety norms. This involves considerable improvement in the social and living conditions — the provision of gas and water supplies, construction of sewage systems, and the provision of permanent radiation and medical monitoring.

4. CONCLUSION

Some considerable time has already passed since the day of the accident and to some of those not directly affected it might seem that the Chernobyl problem has lost its urgency. For many, the memory of the century's most disastrous accident is fading and becoming a thing of the past. This is not the case, however, for the people of Belarus.

Analysis of and predictions regarding the situation indicate that the Republic's own means and resources are not sufficient to deal effectively with the consequences of the Chernobyl accident.

A particular feature of the post-Chernobyl situation in Belarus is that the scale of radioactive contamination and the effect of the radiation burden on a population with the scientific, technical and material resources of a relatively small republic cannot be compared with the other affected States — Russia and Ukraine.

In Belarus we have never had and still do not have nuclear power plants on our territory. We have renounced the possession of nuclear weapons. None the less, we, more than any other State, are having to come to terms with a global disaster. Its consequences will affect the lives of more than one generation. None of the members of the European or the world community has guaranteed immunity from such a situation. The Chernobyl accident has shown that when nuclear events occur on that scale the transfer of radionuclides — even for very short periods — has global connotations. Problems like Chernobyl should be resolved through combined efforts. The United Nations General Assembly resolution 45/190 "International co-operation to address and mitigate the consequences of the accident at the Chernobyl nuclear power plant" makes this point. Chernobyl has forced not only us, but the entire world, to look again at what is happening on our planet. The lessons and bitter experience of the Chernobyl accident, which struck out of the blue, are as much needed by humanity as Belarus needs co-operation in order to ensure a healthy future for present and future generations.

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Report for Ukraine

1. IMPACT OF THE CHERNOBYL DISASTER ON THE POPULATION AND LAND IN UKRAINE

1.1. The Chernobyl accident is the worst technogenic disaster that has occurred in modern times, being unprecedented in its scale and impact. It has affected the economic and social development of a number of countries and the destiny of many generations to come, changing both their living environment and their psychology.

The disaster in Ukraine has resulted in contamination of 3.1 million ha of arable land, 1.5 million ha of natural pastures and hayfields, and 4.4 million ha of forests, which represents approximately 40% of the total forest area of Ukraine. Due to the high level of contamination of more than 40 Ci/km^2, over 180 000 ha of agricultural land are unusable.

The area contaminated with more than 1 Ci/km^2 of caesium-137 is spread over 74 districts in 12 regions and covers about 50 000 km^2. This area contains 2218 settlements in which around 2.4 million people live, including approximately 580 000 children. In 1986, 91 275 inhabitants were evacuated from 76 of these settlements on account of the radiation situation.

The distribution of the population, the settlements, and the areas of the contaminated zones are shown in Table I.

TABLE I.

Population in contaminated areas	Number of settlements	Area (10^3 km^2)	Population	Number of children included
Exclusion zone	76	2.04	91 235 (evacuated)	
Compulsory evacuation zone	92	2.23	19 456	3 658
Guaranteed voluntary evacuation zone	835	23.62	653 263	168 780
Strict radioecological monitoring zone	1291	22.48	1 732 142	406 910
Total	2294	50.52	2 404 861	579 348

There is a high level of potential danger from the 800 temporary radioactive waste stores located within the Chernobyl plant exclusion zone, which were built during the initial clean-up period without the necessary design studies, and do not ensure reliable isolation of the radioactive materials. Waste with a total radioactivity level of over 470 000 Ci is being kept there.

A large quantity of long-lived radionuclides with an activity of over 10 000 Ci is concentrated in the flood plain of the River Pripyat'. A substantial amount of radioactive material is contained in the "shelter" of Unit 4 at Chernobyl nuclear power plant (about 200 tonnes of nuclear fuel, over 20 million Ci of radioactivity), in the cooling pond and at other places in the exclusion zone.

1.2. The Ukrainian law entitled "The status and social welfare of citizens affected by the Chernobyl disaster" specifies four categories of victims.

The first category includes more than 35 000 of those who were involved in the clean-up activities (liquidators) and who consequently became unemployable or contracted radiation sickness.

The second category includes more than 350 000 people who were involved in the clean-up activities in 1986–1987, who were evacuated and who are now living in the compulsory evacuation area.

The third category includes over 550 000 of those who were involved in the clean-up activities (liquidators) in 1988–1990, and persons living in the guaranteed voluntary evacuation area.

The fourth category includes approximately 1.2 million people either living or working in the strict radioecological monitoring zone.

Altogether the total number of people who are receiving benefits and compensation under the law is over 3 million, i.e. around 6% of the total population of the country.

2. ECONOMIC CONSEQUENCES FOR UKRAINE

2.1. The Chernobyl disaster affected either directly or indirectly all regions of Ukraine, had an impact on most sectors of the national economy, and caused appreciable economic, ecological and social damage. In the course of time, it became evident that the consequences of the Chernobyl accident could not be fully eliminated but simply minimized and mitigated.

Table II illustrates the total losses caused by the accident at Chernobyl nuclear power plant.

TABLE II.

TOTAL LOSSES	
Expenditure area	Main cost headings
Design, surveying and production work for the construction of Chernobyl nuclear power plant	— Cost of design and surveying work, site selection, etc.; — Design and construction of plant now taken out of service; — Other costs.
Costs of the initial response to the emergency situation	— Cost of personnel drafted in to deal with the emergency; — Cost of materials, transport services, medical and special care; — Other costs.
Establishment of continuing safety	— Cost of ongoing work to minimize the effects of the accident; — Cost of scientific research and environmental monitoring; — Cost of the whole range of measures to check the quality of food products and to protect water supplies and agricultural land; Other costs.
Cost of reduced production of goods and services, and of industrial reconstruction	— Reduction in electricity production and related goods and services; — Reduction in production in the exclusion zone of the Chernobyl nuclear power plant and the associated reduction in production of other goods and services; — Reduction in the production of agricultural and other goods in contaminated territories.
Cost of the moratorium on the commissioning of nuclear power plant units	— Cost of the shortfall in electricity from the Chernobyl nuclear power plant and other nuclear power plants, and the associated reduction in production of goods and services; — Cost of the work to conserve facilities under construction and in operation; — Other costs.
Cost of non-use of production and other facilities	— Cost of production facilities taken out of service; — Cost of living accommodation and other non-production facilities.

TABLE II. (cont.)

TOTAL LOSSES	
Expenditure area	Main cost headings
Cost of evacuation and relocation	— Construction of new living accommodation and social facilities; — Cost of relocation, transport, etc.; — Cost of conservation, protection, etc. of abandoned living accommodation and property.
Cost of measures relating to health protection and social welfare	— Cost of medical care for victims of the accident; — Cost of pensions, benefits, compensation, etc.
Cost of natural resources which are no longer usable	— Cost associated with unusability of contaminated water and forestry resources; — Cost of the unusability of land; — Loss of income from the recreational use of water, forestry and other natural resources.
Financing of measures in the exclusion zone of Chernobyl nuclear power plant	— Cost of measures to stabilize the ecological situation in the exclusion zone of Chernobyl nuclear power plant; — Cost of establishment, operation and refinement of the radioecological monitoring system; — Cost of measures for processing and burial of radioactive wastes; — Cost of measures to prevent the spread of radionuclides beyond the exclusion zone (water protection measures, protection from forest fires, etc.); — Other costs.
Cost of decommissioning Chernobyl nuclear power plant and other facilities affected by the accident, solution of the problem of the "shelter" of Unit 4 of Chernobyl nuclear power plant	— Development of comprehensive programmes, technical specifications, feasibility studies and project plans and cost estimates for decommissioning; — Direct cost of decommissioning and subsequent work to maintain the facility; — Cost of restructuring the development of the region; — Cost of the work to stabilize the existing "shelter" and to create "Sarcophagus 2".

The above classification of the losses resulting from the accident at Chernobyl nuclear power plant does not include certain significant items, the economic value of which is difficult to determine clearly, for example, the cost of human lives which have been prematurely brought to an end, deterioration of people's health, political damage, loss of electricity markets in Eastern and Western Europe. Moreover, it is difficult to quantify losses caused by erosion of cultural and moral values, etc.

An exact calculation of all the losses listed in the table is also difficult. This is primarily due to the fact that since 1986 there has been no systematic comprehensive evaluation of all expenditure on dealing with the consequences of the accident. With the break-up of the former USSR, the formation of the independent States and the various bodies responsible for mitigating the consequences of the accident, precise determination of the total losses on the basis of the above classification remains a complex scientific and practical problem. According to expert evaluations, the losses to Ukraine resulting from the Chernobyl disaster are of the order of hundreds of billions of dollars.

2.2. Up to September 1991, effort on mitigating the consequences of the Chernobyl accident and providing social services to the public was financed directly from the budget of the former USSR; since September 1991, it has been financed from the budget of Ukraine.

The main source of finance is the special Fund for Measures to Eliminate the Consequences of the Chernobyl Disaster and Provide for Social Welfare of the Public (LPA Fund), which is maintained by contributions from firms and commercial organizations, irrespective of their type of ownership or who controls them; these contributions amount to 12% of the payroll, with the cost being added to the cost of the goods or services supplied by those concerns. This Fund was set up in December 1991 by decree of the Ukraine Supreme Soviet. (See Table III.)

TABLE III.[a]

Year	GDP		National Income		LPA Fund	
	Actual prices	% of real GDP compared to previous year	Actual prices	% of real national income compared to previous year	Actual expenditure	% of national income
1991	299.4	91.3	224.3	86.6	6.2	2.8
1992	5 032.7	90.1	3 887.1	82.5	97.6	2.5
1993	148 273	85.8	118 273	81.2	1 966	1.7
1994	1 337 794	77.0	967 046	75.5	23 788	2.5
1995	5 293 300	88.2	4 145 611		94 199	2.3

[a] The data are presented in billion karbovanets at prices for the corresponding years.

Despite the annual fall in GDP and national income of Ukraine, the cost of minimizing the consequences of the Chernobyl disaster has continued to vary between 1.7% and 2.8% of the national income.

Table IV presents calculations of the proportion of the LPA Fund in the State budget at prices for the corresponding years in billion karbovanets. It fluctuates from 6.4% (max) in 1992 to 5.1% (min) in 1994.

For comparison, data from the Ukrainian Ministry of Statistics show that State budget expenditure in 1993 on minimizing the consequences of the Chernobyl accident was 105.4% of the total expenditure on defence. In 1995 this indicator reached 110.6% or, taking into account the cost of work at Chernobyl nuclear power plant, 116.6%.

In a simplified calculation using the official exchange rate, the total expenditure on minimizing the consequences of the accident amounted to more than $3 billion over the past three years. However, taking into account the real purchasing power of the Ukrainian karbovanets and domestic price levels, the costs of the Chernobyl programmes may be significantly higher.

Table V presents the proportionate expenditures of the programme to minimize the consequences of the Chernobyl disaster over the period 1992–1995. There is a clear increase in the proportion of resources earmarked for social programmes and reduction in capital investment.

When estimating forthcoming expenditure, account must also be taken of the fact that the long-term effects of the Chernobyl disaster and their impact on human health have still been insufficiently studied and forecasted by scientists. If the worst prognosis comes true, there may be an increase of some illnesses, which could result in additional expenditures for medical care, social security, etc.

TABLE IV.

No.	Indicators	1992	1993	1994	1995
1	Planned State budget expenditure	684.47	43 137.0	468 103.1	1 860 379.1
2	Planned LPA Fund expenditure	155.4	2 120	23 905.8	117 481.92
3	Proportion of LPA Fund in State budget plan, %	22.7	4.9	5.1	6.3
4	Actual budget expenditure	1 513.1	37 306.0	486 224.0	1 609 600
5	Actually financed from LPA Fund	97.65	1 966.42	23 788.4	94 199
6	Proportion of LPA Fund in actual State budget expenditure, %	6.4	5.3	5.1	5.8

TABLE V.

Proportion of the total funding expended on separate sections of the programme	1992	1993	1994	1995
Social welfare	39%	45%	63%	66%
State capital investment	49%	43%	24%	18%
Independent relocation of inhabitants of contaminated areas	5%	3%	3%	4%
Financing of work in the exclusion zone of Chernobyl nuclear power plant	4%	6%	6%	6%
Other	3%	3%	4%	6%
Total	100%	100%	100%	100%

The problem of the "shelter" around the destroyed Unit 4 of the Chernobyl nuclear power plant is an acute one. It was built under extreme radiation conditions in a short period of time, and the problem of stabilizing it and building a new containment shell, "Sarcophagus 2", is already upon us. According to the feasibility study of the project to make the shelter into an ecologically safe system, which was carried out under the aegis of the European Commission, between 900 and 1500 million dollars would be required for this purpose. Such a large expenditure is clearly beyond the means of Ukraine.

Significant additional outlay will be necessary for the creation of a radioactive waste management system. The construction of waste stores, the organization of a transport system, an accounting system and the burial and reburial of radioactive waste from Chernobyl, industry and medicine will involve significant cost, and complex scientific, technological and organizational problems will need to be solved.

With the Ukrainian economy on a downward trend, the costs of minimizing the consequences of the accident are becoming an ever greater burden for it. Nor does the additional Chernobyl tax burden help to stimulate the economy and increase the production of goods and services.

Thus, it may be concluded that the negative effect of the Chernobyl disaster on the national economy of Ukraine *has not only not decreased but is continuing to increase*. Despite the vast countermeasures which have been undertaken to date, many major problems remain unsolved and will require significant expenditure in the near future. However, it should be noted that the expenditure on eliminating the consequences of the Chernobyl disaster has not been wasted. The countermeasures have in fact helped to mitigate many of the problems thrown up by the accident.

3. POLITICAL, LEGISLATIVE, ADMINISTRATIVE AND OTHER CHANGES RESULTING FROM THE ACCIDENT IN UKRAINE

3.1. The years following the Chernobyl disaster have borne convincing witness to its substantial impact on political life in Ukraine. Coinciding as it did with the growth of democracy and glasnost, as well as socioeconomic perestroika of State and society, the Chernobyl disaster became the subject of keen political and ideological struggle. In 1990, the Supreme Soviet of the Ukrainian SSR undertook a broad-ranging examination of the ecological situation in the Republic and, in the light of the consequences of the accident, declared Ukraine an ecological disaster area.

3.2. In June 1990 the Supreme Soviet of the Ukrainian SSR appointed from its deputies a Standing Commission to deal with issues related to the Chernobyl disaster and in August passed a resolution on urgent measures to protect the citizens of Ukraine from the consequences of the Chernobyl disaster. The Commission did much preparatory work for laws concerning the accident at Chernobyl nuclear power plant. At the end of February 1991, the Supreme Soviet of the Ukrainian SSR adopted the "Concept for habitation by the population of areas of the Ukrainian SSR with high levels of radioactive contamination resulting from the Chernobyl disaster", as well as laws on the legal status of land affected by radioactive contamination as a result of the Chernobyl disaster and on the status and social welfare of citizens suffering as a result of the Chernobyl disaster. In subsequent years certain amendments and additions were made to these laws to meet requirements arising from their practical application and to adapt to the changing radiation situation.

The passing of these legislative acts was of great socio-political significance and helped to stabilize socio-psychological conditions in society. Thus, the Concept enabled a systematic approach to be developed to eliminate the consequences of the accident, determined criteria and priorities to be followed in carrying out measures concerned with protecting the population, rehabilitating affected land and researching the consequences of the accident. At the same time the law on the legal status of affected land regulated the division of land into zones, determined the conditions for their use and protection, defined the living and working conditions of the population and underlined the prime importance of pursuing research and undertaking protective measures.

The law on the status and social welfare of citizens established the rights of Ukrainian citizens to compensation for damage to their health and property resulting from the disaster, to preferential medical treatment, and to entitlements and compensation for living and working in the contaminated areas. It also determined the categories of citizens suffering from the consequences of the disaster and the corresponding forms and levels of monetary compensation and entitlements.

The enactment of these new laws and the development of appropriate mechanisms for their implementation required a major organizational effort, first and foremost, in relation to social welfare issues. A wide-ranging resolution of the Ukrainian Cabinet of Ministers issued a directive to Ministries and Departments, which thereupon prepared more than 100 regulatory documents, instructions and guidelines. Appropriate radiological services were set up in institutions involved in the campaign to eliminate the consequences of the accident.

3.3. In this connection, and also as a result of an assessment by Ukraine's leadership of the scale and duration of the impact of "Chernobyl" factors on the ecology and socio-economic sphere of the country, the Ukraine State Committee on Chernobyl was set up at the end of 1990 (from May 1991 called the Ministry for Elimination of the Consequences of the Chernobyl accident — MinChernobyl). Its main task is to implement State policy on minimizing the consequences of the Chernobyl disaster and protecting the population from their impact.

The corresponding hierarchical divisions were created in the Executive Committees of the regions most affected. After the decree of the President of Ukraine of 28 May 1993 was issued, steps were taken to set them up in the other affected regions (at the present time there are 12 Chernobyl directorates). In autumn 1995, by decree of the President of Ukraine, the directorates were placed under dual authority — reporting to both the head of the State administration of the region and MinChernobyl. In this way a direct line of authority was established for tackling problems caused by the Chernobyl disaster.

In the administrative structure of the bodies responsible for carrying out the work to minimize the consequences of the Chernobyl disaster, the Exclusion Zone Administration of MinChernobyl holds a special place. It is a special division of the central MinChernobyl organization, located directly in the town of Chernobyl, with responsibility for co-ordinating countermeasures and scientific investigations being undertaken in the exclusion zone, and issues related to their financing. The decisions of the Exclusion Zone Administration are binding for all undertakings, associations and organizations carrying out work in the exclusion zone, irrespective of their hierarchical status. Land from which the affected population has been resettled also comes under the control of the Exclusion Zone Administration. The administrative structure is as shown in Fig. 1.

4. DEMOGRAPHIC ASPECTS AND LIVING CONDITIONS IN THE AFFECTED AREAS

4.1. As indicated in Section 1 of this report, according to current Ukrainian legislation 2218 settlements are located in contaminated zones (not including the exclusion zone) in 12 regions in Ukraine with, on 1 January 1995, a total population of 2 404 861, of whom 579 348 were children below the age of 15.

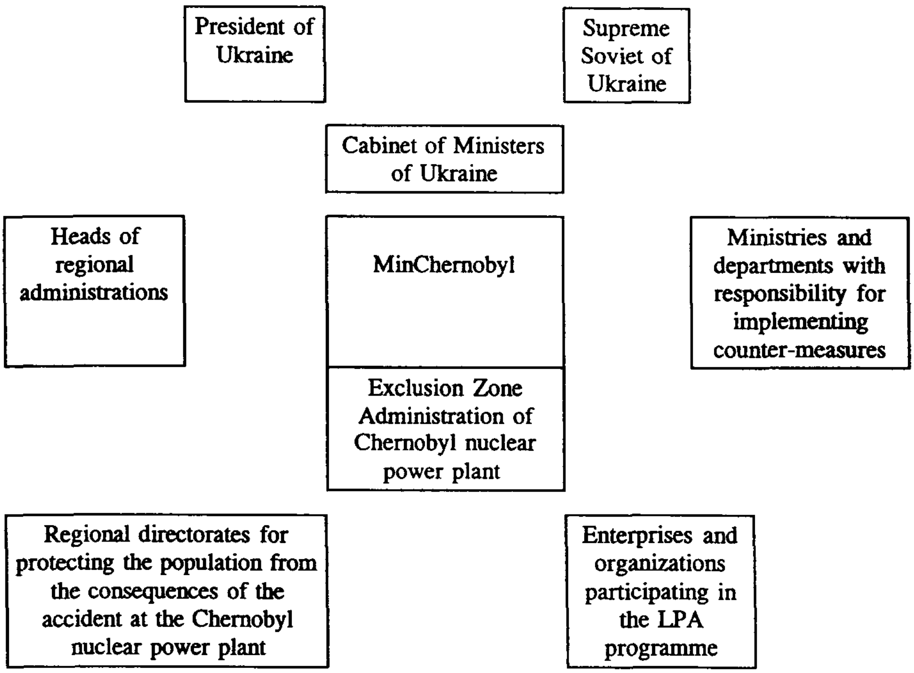

FIG. 1. Administrative structure.

Studies of the impact of the Chernobyl disaster on the life of the population in the contaminated areas are being performed taking into account ecological, economic and socio-psychological factors.

Analysis of the medical and demographic situation has revealed changes in practically all demographic indicators. Tables showing the change in mortality and birth rate of the population are included in the Annex. They reveal a marked increase in mortality in the contaminated areas (Narodichi, Ovruch, and other areas) compared with the statistical mean for Ukraine. Particularly worrying is the significant increase in infant mortality in these regions.

According to surveys carried out by the Council for the Study of Productive Forces of the Ukrainian Academy of Sciences (SOPS NAN), there is a decreasing trend in the population in zones 2 and 3, while in other regions of Ukraine it is increasing. This is due to both migratory and natural movement of the population.

The drop in population due to evacuation, planned resettlement of the population and independent exodus of people to non-contaminated areas has led to a change in the territorial distribution of the population, to distortion of the age/sex structure of those remaining in contaminated areas, and to an increase in their average age.

Thus, the proportion of pensioners and individuals receiving pensions, grants, etc. in the affected areas has increased. The birth rate is declining and mortality is increasing. As a result, conditions in the contaminated zones have become unfavourable for the development of new generations and for their health.

There has been a sharp decline in standard of living since the onset of the economic crisis at the beginning of the 90s. Owing to the wholesale economic transformation, the transition from planned production to a market economy and change in forms of ownership, a considerable number of industrial enterprises are not working to their full capacity and are experiencing problems in selling their products, etc. Lack of investment, outdated equipment and technology and the uncompetitiveness of the goods produced, both in internal and external markets, have led to a rise in unemployment. As in other parts of Ukraine, unemployment in the contaminated areas is mainly hidden — firms work a short week, and enforced leave is taken for periods of up to several months. There are long delays in the payment of salaries, and of benefits and compensation for victims of the accident.

In addition to economic and ecological factors, the processes of glasnost and perestroika have also had a significant effect on society. Against the background of the many restrictive and prohibitory measures imposed on inhabitants of the affected areas, the mass media failed to give a full account of the true scale of the disaster in the early years following the accident.

Socio-psychological factors too have affected the state of health of the population in the contaminated areas of Ukraine. A high level of anxiety about potential radiation effects, compounded by economic and ecological factors, has caused various categories of those affected by the accident to adopt an increasingly negative viewpoint regarding their own health. Thus, tests of people's perceptions and level of satisfaction regarding their state of health have revealed a consistently low assessment of personal health among those living in the contaminated areas. Among people questioned there, around 90% are alarmed about their own health and that of their close relatives, and 68% consider that the existing radiation situation is dangerous to health.

5. ECONOMIC DEVELOPMENT OF THE CONTAMINATED AREAS

5.1. The Chernobyl disaster caused considerable damage in parts of Ukraine to the economy, ecology and socio-cultural sphere, which has had a considerable impact on subsequent socio-economic development. The areas affected are not among the most economically and socially developed (with the exception of the city of Kiev and the Kiev region), but considerable resource potential is concentrated in these areas, and its total value, according to SOPS NAN estimates, constitutes a significant part of the national wealth.

The most important disaster-induced factors affecting economic development in the contaminated areas and the State as a whole include the loss of production capacity, the unusability of agricultural land and forest, a reduction in electricity generation, social and psychological effects, and migration. Coupled with the severance of production and scientific and technical links following the collapse of the former USSR, the need to finance efforts to minimize the consequences of the accident at Chernobyl nuclear power plant has exacerbated the economic recession in Ukraine.

The main factors influencing the economic development of the affected regions after the disaster have been:

— Changes in the running of agriculture and industry associated with processing of agricultural and forest products;
— Deterioration in the health of the population, changes in the employment structure, and population changes due to relocation and migration to other regions;
— Inadequate supply of fuel and energy resources to the national economy and their territorial distribution.

The consequences of the disaster have had the greatest impact on the development of areas where the effect of radioactivity coincided with already existing technogenic factors. Techno- and anthropogenic burdens, together with radioactive contamination, have had the greatest impact on the development of the agro-industrial complex and the water industry. It should be borne in mind that agricultural land constitutes 70% of the total land area of Ukraine (compared with 25% for the former Soviet Union as a whole), and arable land makes up 57% (compared with 10%).

In the agro-industrial production sector, changes have occurred in farm specialization and the structure of the areas under crops, new crop rotations and labour and resource saving technologies have been introduced, restructuring of production is continuing and the range of crop varieties is changing. There have been appreciable changes in the structure of areas under crops. As a rule, the area under food crops is decreasing, while the area under fodder crops is increasing. In affected regions the area of arable land has been reduced, the total number of cattle has been cut back and the processing industry has been reorganized.

Owing to the Chernobyl disaster, electricity generation in Ukraine has fallen and structural changes in regional electricity production are planned. Considerable losses in electricity production will result from the moratorium on the commissioning of new nuclear power plant units. According to economists' calculations, in value terms a single unit of electricity entering other branches of the economy secures a 20 unit increase in the national income.

The fall in electricity generation, and the need for restructuring of the economy have had a significant impact on the development of production in such sectors as the processing, light and food industries. As a result of the disaster, there was an annual shortfall in production in the contaminated areas amounting to tens of millions of dollars.

The closure of Chernobyl nuclear power plant without the substitution of sufficient extra capacity and without compensatory foreign aid could lead to a worsening of the energy and economic crisis.

Inadequate development of the social and cultural sectors to meet the needs arising in the wake of the disaster has had a negative impact on the development of affected areas. Rural health care, along with its material and technical basis, is particularly unsatisfactory. Almost half the district hospitals and outpatients' clinics in rural areas are in unsuitable premises, lacking hot water supplies, telephone lines, ventilation, etc. Not enough resources were earmarked after the disaster to ensure satisfactory development in the social and cultural sphere in the contaminated areas, and capital investment in this sector was given the lowest priority.

5.2. An economic revival in the contaminated areas requires in the first instance considerable capital investment in order to construct industrial plant and housing and establish a regional infrastructure, engineering facilities, roads, etc. It is feasible to develop the processing of farm and forestry products in the region. Much will depend on attracting investment, including foreign investment, to modernize obsolescent equipment and develop competitive industries and a modern economic infrastructure. To achieve that aim, potential investors need to be offered various incentives. At the moment, no stable source of investment exists for these purposes other than the "LPA Fund" mentioned above.

6. CONCLUSIONS AND RECOMMENDATIONS

Since the accident, a vast effort has been made to protect the population, rehabilitate the affected areas and study all the consequences of the accident. The countermeasures undertaken have helped to reduce significantly the dose burdens to the population, contain the spread of radionuclides beyond the boundaries of the contaminated areas, and laid the foundations for a systematic campaign to minimize the long-term consequences of the Chernobyl disaster. However, the current state of Ukraine's economy is such that not all the necessary protective measures can be undertaken.

The main conclusions drawn from the experience of the past ten years and the results of scientific research relate to the need for action in the following areas:

- The promotion of nuclear and radiation safety;
- The carrying out of comprehensive radiological monitoring and the creation of a system for predicting changes in the radiation situation and exposure doses;

— The creation of living and working conditions for the rural population which comply with radiation safety standards;
— The implementation of countermeasures in agriculture and forestry;
— Comprehensive health care measures;
— The development of a legal basis for protection of the population;
— Public information and socio-psychological rehabilitation;
— The creation of a radioactive waste management system.

In particular it is necessary:

— to implement measures to increase the safety of existing reactors, to develop safety culture and to improve the corresponding regulatory and organizational basis;
— to improve the system of radiation monitoring in Ukraine as a whole and around potentially dangerous facilities in particular, predict the consequences of potential emergency situations of a natural or technogenic nature, model their development and elaborate ways of localizing them;
— to develop an emergency and radiation medicine system, carry out comprehensive studies of the health of the affected population, in particular people who took part in the clean-up following the Chernobyl accident;
— to develop in Ukraine a system for managing radioactive waste resulting from decontamination measures and waste of industrial and medical origin, and to implement measures to ensure the safety of provisional storage sites for waste and, if necessary, relocate it;
— to continue scientific studies, implement anti-flood, fire prevention and health-protection measures in the contaminated areas, limit industrial activity in the exclusion zone, and restrict public access to it;
— to continue measures to restructure the agricultural and forestry industries, create radiation safe working conditions, implement measures to reduce the radionuclide content in agricultural produce, improve the efficiency of production and processing and create competitive products and modern distribution networks;
— to continue measures aimed at limiting consumption by the population of food with a high radionuclide content, continue monitoring of forestry products and introduce special methods for their processing;
— to implement social and economic rehabilitation of the contaminated territories, improve the amenities of settlements and develop the necessary cultural, domestic and economic infrastructures;
— to pursue an active and continuing public information policy and inform as many people as possible about the principles of radiation safety.

The advisability of continuing with particular protective measures should be considered taking into account the factors determining previous policy, as well as the costs and benefits of implementing such measures.

ANNEX

TABLE A.1. MORTALITY RATES IN THE CONTAMINATED AND MONITORED DISTRICTS OF UKRAINE OVER THE PERIOD 1985–1994 (per thousand people)

Districts	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Luginy	11.8	12.5	10.8	12.8	13.1	13.5	16.7	15.9	18.0	17.2
Narodichi	19.3	16.7	17.5	18.4	17.8	20.0	19.4	25.7	28.9	29.8
Ovruch	14.3	12.3	13.0	14.5	13.6	14.7	15.8	16.0	17.9	17.9
Ivankov	18.4	16.9	18.1	18.7	21.1	19.8	20.2	19.9	22.0	24.1
Polesskoe	16.3	17.2	20.5	19.7	15.9	17.6	19.4	21.4	28.0	23.6
Kozelets	17.8	15.9	17.4	17.5	18.2	19.4	20.1	21.8	23.2	24.9
Repki	20.4	16.1	18.7	18.8	16.8	18.4	20.2	21.1	21.8	23.2
Chernigov	16.0	15.2	15.6	16.2	15.3	16.2	17.4	18.8	20.8	20.6
Lokhvitsa	17.2	15.7	15.8	17.7	15.8	17.5	18.0	20.7	21.5	21.2
Ukraine	12.1	11.1	11.4	11.6	11.6	12.1	12.9	13.4	14.2	14.7

TABLE A.2. BIRTH RATES IN THE CONTAMINATED AND MONITORED REGIONS OF UKRAINE IN KIEV OVER THE PERIOD 1985–1994 (per thousand people)

Regions	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Zhitomir	15.3	15.7	14.0	14.2	13.7	12.9	12.9	12.8	12.4	11.8
Chernigov	12.9	13.4	12.6	12.4	11.7	10.8	10.1	9.8	9.4	8.9
Poltava	13.1	14.1	13.8	13.4	12.4	11.8	11.5	10.8	10.0	9.5
Kiev City	15.6	14.4	12.7	14.8	13.6	12.0	11.0	9.7	8.6	8.1
Ukraine	15.6	15.5	14.8	14.4	13.3	12.7	12.1	11.4	10.7	10.0

TABLE A.3. INFANT MORTALITY RATES IN THE CONTAMINATED AND MONITORED REGIONS OF UKRAINE AND IN KIEV CITY OVER THE PERIOD 1985–1994
(per thousand live births)

Regions	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Zhitomir	14.3	13.5	14.9	11.3	11.2	14.5	14.6	13.6	14.4	15.7
Chernigov	12.6	13.1	12.3	12.1	12.3	10.1	12.0	12.5	12.4	12.8
Poltava	14.2	13.0	12.3	12.5	11.9	12.7	11.2	12.7	10.7	12.0
Kiev City	16.7	15.7	16.2	15.9	13.4	12.7	14.1	17.2	17.5	15.9
Ukraine	15.7	14.8	14.5	14.2	13.0	12.9	13.9	14.0	14.9	14.5

DISCUSSION ON BACKGROUND PAPER 6

M. PAVLOVSKY (Ukraine): I believe that, thanks to the experience of dealing with radioactivity which it has gained as a result of the Chernobyl accident, Ukraine is now in a position to produce and export a range of domestically developed "radioprotectors" and that a project to that end should be launched.

I also believe that the possibility should be explored of exporting to various European countries agricultural produce from those parts of Ukraine which were not contaminated by the Chernobyl accident. Such produce is radioactively "clean", and — in contrast to much of Western Europe's agricultural produce — very little in the way of chemical fertilizers and herbicides is used in growing it.

V.I. KHOLOSHA (Ukraine, Rapporteur): With regard to the production and export of "radioprotectors" developed in Ukraine, the idea is an interesting one, but the absence of undesirable side-effects should first be established with a view to having such "radioprotectors" certified by the relevant pharmaceutical bodies.

With regard to the possibility of exporting Ukrainian agricultural produce to various European countries, the agricultural produce from central and southern Ukraine conforms to the highest international standards of ecological "purity". The possibility certainly deserves to be explored.

V. YATSENKO (Ukraine): I should like to make a number of points speaking as a politician, although there have been a lot of uncomplimentary remarks about politicians in connection with the Chernobyl accident.

First, many people have spoken disparagingly of the "non-professionals" (even "dilettantes") — as opposed to "professionals" — involved in dealing with the consequences of the accident. It should be remembered, however, that the accident was caused by "professionals" and that the main burden of dealing with its immediate consequences was borne by "non-professionals", who deserve credit for their efforts.

Second, we politicians have been accused of taking ill-considered decisions following the accident. It was not until 1989–1990, however, that we discovered the true situation regarding the radioactive contamination, at which point we took more or less considered decisions in the light of that situation — without political pressure.

Third, we are now taking decisions on the basis of the fact that special medical commissions in Ukraine have linked the disabilities of some 50 000 liquidators and other persons to the consequences of the Chernobyl accident and that every month such a link is established in a further thousand cases — and I am not talking about sufferers from acute radiation sickness.

Fourth, we take the — I think — reasonable view that people have the right to live and raise their children without undue restrictions and that forbidding children to walk through the grass barefoot, prohibiting the consumption of mushrooms and berries from the woods and similar restrictive measures constitute an infringement of human rights.

Fifth, the Ukrainian people are beginning to die out. Each month, deaths exceed births in Ukraine by twice the number of fatalities suffered by the Soviet Union during the war in Afghanistan, the population decline being 2.5 times as high in the contaminated regions as in the "clean" regions.

Sixth, in 1995 the average monthly wage in the rural parts of Ukraine affected by the accident was about US $15, corresponding to about US $7 per head of the population when children and other non-earners are taken into account. The monthly compensation and other payments amount to no more than US $5 per person. The average family income is therefore not very high, and I invite those attending this conference to try living for a month on such an income. They would soon conclude that the talk about excessively high levels of compensation is unjustified.

Seventh, it was people — like medical personnel — who understood the effects of ionizing radiation who tended to leave and stay away from the contaminated areas, so that in many villages the medical centres have been closed down and medical assistance is available only from time to time.

We are grateful to the liquidators who came to help in the areas affected by the Chernobyl accident. They have left now, however, and in those areas there remain people who have to live with the radiation situation for years to come. They want — from the "professionals" — reliable guarantees for themselves, their children and their grandchildren that they will be able to lead normal lives. It would be nice if they could be given such guarantees now — not on the 20th or 50th anniversary of the Chernobyl accident.

W. PAILE (Finland): It has been stated that the health of the people living in contaminated areas is deteriorating. However, I am not convinced that such statements are based on solid data; you cannot simply compare the number of diagnoses of illness made in a population undergoing obligatory annual health checks with the number of diagnoses of illness made in a population not undergoing such checks.

Moreover, it is not surprising that mortality rates are rising; young women and children have been moved out of the contaminated areas, so that elderly people now account for larger fractions of the populations — with an obvious impact on the mortality statistics.

In this context, I would mention that when we examined 30 children from Belarus who were all certified as having some illness or other and had been brought to spend some time in a Finnish summer camp, we found that all of them were 100% healthy. Such an experience also raised doubts about the statistics which we have been given.

Lastly, we have heard about the 35 000 liquidators in Ukraine who have been declared invalids as a result of radiation sickness. However, radiation sickness implies doses of at least 1-2 Gy, and even a dose of 2 Gy — while causing radiation sickness — does not lead to permanent invalidity. Consequently, I do not believe that those 35 000 liquidators are invalids because of exposure to ionizing radiation.

I.V. ROLEVICH (Belarus): As a physician I cannot ignore such statements. I have complete confidence in the physicians coping with the consequences of the Chernobyl accident in Belarus, the Russian Federation and Ukraine. They are working closely with WHO on the basis of international standards, and morbidity rates are computed the same way in the three Republics as elsewhere in the world.

C. ZUUR (Netherlands): I should like to express support for what Dr. Paile just said. The children living in affected areas of the three Republics may well deserve a holiday abroad, but the 200 or so children whom we have had in the Netherlands were healthy — apart perhaps from problems caused by a lack of vitamin C, due probably to shortages of fresh vegetables.

O. BOBYLEVA (Ukraine): With regard to the matter raised by Dr. Paile, the three Republics have State health care systems. Accordingly, I appeal to those organizations which wish to help children from the three Republics to do so in co-operation with the State organs responsible for health care. As a physician I give my word that it is the opinion of the competent physicians which is decisive in the selection of the children who are to be sent abroad.

V.K. HOMICH (Belarus): Over the past ten years, many mistakes have been made by scientists in connection with the Chernobyl accident. The scientists involved in dealing with the accident's consequences may be divided into three groups: professionals in the field of radiology; professionals in the field of nuclear facility operations; and scientists working in a variety of other fields who may be considered "non-professionals" as far as radiology and nuclear facility operations are concerned. It is such "non-professionals" who came up with the concept of "radiophobia" and caused the media to exaggerate the consequences of the accident.

In order to minimize the accident's consequences, it is necessary to devise approaches which take into account all aspects — the radiation aspect; the public information aspect; the psychological, medical, social, economic, legal and political aspects; the international aspect, etc.

At present there are no damage assessment methods which take into account the radiation factor, and it is necessary to develop such methods for specific affected areas. Once such methods have been developed, it will be necessary to take them into account in developing methods for ensuring the proper distribution and effective utilization of material resources.

In addition, it is necessary to develop uniform international legal guidelines for radiation accidents and to ensure that the standards relating to foodstuffs in countries affected by radiation accidents are uniform.

P. HEDEMANN JENSEN (Denmark): There seems to be a discrepancy between the increased mortality due to cancer mentioned in the Belarus national report and the conclusion in Background Paper 3 on long term health effects that, except for thyroid cancer in children, it will not be possible to detect any increase in cancer incidence related to the Chernobyl accident. Perhaps Prof. Rolevich would care to comment on this.

I.V. ROLEVICH (Belarus): The Belarus national report was based on data obtained through the careful examination of people attending community clinics and analysis of the Cancer Registry. The data, which point to an increasing incidence of tumours of the urogenital system (especially the urinary bladder and the kidneys) in the four most contaminated areas in Belarus, are strictly scientific and objective, but they have yet to be confirmed.

P. HEDEMANN JENSEN (Denmark): It appears that — in Belarus, the Russian Federation and Ukraine — the radiation doses which can be averted through the countermeasures being applied are, on average, no higher than the doses due to the natural background radiation. I should therefore like to know whether the countermeasures in question are being applied for radiation protection purposes or on socio-psychological grounds.

I.V. ROLEVICH (Belarus): The countermeasures being applied in Belarus form part of a programme covering the period 1996–2000. For reasons of cost, some agricultural countermeasures (such as the more intensive use of fertilizers) are not being applied in all areas. In fact, given the economic situation in Belarus we cannot resolve the radiation dose problem with countermeasures alone.

P. HEDEMANN JENSEN (Denmark): The criteria being applied in Belarus, the Russian Federation and Ukraine differ among themselves and from the international criteria recommended by ICRP. Would it not be a good idea to harmonize the criteria being applied in the three Republics?

I.V. ROLEVICH (Belarus): The three Republics are maintaining close contact with ICRP, and I think there will be harmonization of the criteria in due course.

V.I. KHOLOSHA (Ukraine, Rapporteur): The differences between the three Republics as regards criteria relate primarily to the concentrations of radionuclides in agricultural produce. Here, the Belarus criteria are less stringent than our criteria, which in turn are less stringent than the FAO criteria. What is perhaps more important than the criteria, however, is the intervention levels.

V.A. VLADIMIROV (Russian Federation, Rapporteur): In the interests of protecting the population, the authorities in any country will no doubt wish to make the criteria relating to foodstuffs more stringent. However, the country's economic situation may necessitate compromise in this area.

P.V. RAMZAEV (Russian Federation): The question of "non-professionals" and "professionals" — which is essentially one of politicians and scientists — is a complex one. In the former Soviet Union, there were even attempts by politicians to have various scientists put behind bars after the Chernobyl accident. For example, Academician Ilyin was very lucky to escape such a fate.

The intervention criteria worked out by the IAEA, ICRP and other bodies are reflected in the new radiation safety standards of the Russian Federation and Belarus, and according to those criteria resettlement is justified only if a lifetime dose of 1 Sv can be averted, while other measures are justified if the expenditure on averting 1 man·Sv does not exceed the annual national income per head of population.

In the light of those criteria, with the exception of Pripyat the evacuation of people out of the 30-km zone was unjustified, while the amounts being spent on various measures are hundreds of times more than what is justified. The losses due to the Chernobyl accident represent only 5% of the losses due to the bombing of Hiroshima, and in the Russian Federation the radiation doses resulting from the Chernobyl accident are 0.3% of the 70-year dose, but the accident has nevertheless been converted into a catastrophe.

I.I. LISHTVAN (Belarus): I disagree with those who are playing down the effects of radiation on people's health in the regions affected by the Chernobyl accident. The medical and biological studies confirming the existence of such effects are, in my view, of a high professional standard.

At the same time, I should like to know what is being done about the synergism between contamination due to radioactivity and that due to chemicals.

V.I. KHOLOSHA (Ukraine, Rapporteur): Such synergism, which I consider to be very important, is being studied. More work should be done on it as it may explain various observed effects which are not related to radiation dose.

A.R. OLIVEIRA (Brazil): After a radiation accident there is an increase in the number of supposedly affected people when the authorities announce a scheme for compensating the accident victims, with the media, trade unions and others pressing for persons who — they claim — are suffering or will suffer as a result of the accident to be included in the group of people who were without doubt directly affected. This is a sensitive matter, and I should be interested in hearing other people's views regarding it.

J. LOCHARD (France, Chairperson): It is indeed a sensitive matter. Some 30–50% of the financial resources allocated for mitigating the consequences of the Chernobyl accident are being used for compensation purposes, and it would be useful to consider how such large amounts might best be used for the benefit of the population as a whole.

V.I. KHOLOSHA (Ukraine, Rapporteur): In Ukraine, no increase in the overall number of persons affected by the accident is taking place. However, the number of those worst affected — persons who have suffered from radiation sickness and are no longer able to work — is rising. That number may include some cases which do not quite qualify, but essentially I have no grounds for distrusting the data put out by our Ministry of Public Health.

As regards levels of compensation, those worst affected by the accident receive on average about US $5000 a year each. By contrast, those less affected persons who are living in the least contaminated areas (and who account for most of the affected population) receive on average about US $100 each. I think this is fair — those who really suffered should receive substantially more than those who are simply being monitored.

V.A. VLADIMIROV (Russian Federation, Rapporteur): We are trying to ensure that compensation is paid only where it is really needed. Thus, we are proposing that compensation no longer be paid to the people living in areas with contamination levels of 1–5 Ci/km^2, who are now receiving doses below the permissible limits and growing agricultural produce which conforms to the established norms, and that the funds released in this way be used for compensating those living in areas where the doses received are in excess of the permissible limits and the levels of contamination of the agricultural produce are higher than those foreseen in the established norms.

C. ZUUR (Netherlands): I would suggest that, certainly in Belarus, compensation payments to liquidators be made only after they really fall ill — not beforehand on the grounds that they have received high radiation doses. The money thus saved could be used to improve health care — especially the treatment of thyroid cancer.

I. LIKHTAREV (Ukraine): I support the idea of focusing compensation payments on those who actually contract thyroid cancer and related diseases, rather than spreading the resources in question over a huge number of persons each of whom will receive only a very small amount.

O. BOBYLEVA (Ukraine): With regard to the liquidators in Ukraine, I believe that 90% of the physicians attending this conference would, after examining the medical documentation on those people, certify over 90% of them as invalids.

A major question is whether their invalidity is linked to the Chernobyl accident. In my opinion, in the light of the data on the itineraries of those people and on the risks to which they were subjected when they were working as liquidators we cannot deny that there is a link.

S.T. BELYAEV (Russian Federation): In most areas contaminated as a result of the Chernobyl accident, the psychological consequences were more serious than the radiological ones. This fact must be borne in mind in the planning of countermeasures. For example, two or three years ago the whole-body caesium counts for people living in the most contaminated parts of Bryansk oblast began to rise. We found that this was due to a sharp increase in the number of cows being kept on private smallholdings, which was clearly a sign of a return to a more normal way of life and thus represented a positive psychological change more important — in my view — than a slight increase in radiation dose.

In such situations one should avoid being alarmist and allow people to improve their own situation; one should create favourable conditions for development of the local economy rather than making compensation payments, which simply tend to make people passive and more dependent.

J.S. NATHWANI (Canada): In my view, the enormous social and economic effects of the Chernobyl accident are a direct consequence of the displacement of large populations; the disruption and post-traumatic stress disorders arising from deep anxieties about the future are real, and — coupled with poor living conditions — they have resulted in total human deprivation that cannot be ignored.

Our excessive concern in the area of radiological protection is so narrowly focused and the standards we have set for radiological safety are so stringent that we have inadvertently created a much larger risk; when a decision has to be taken about countermeasures, in the face of uncertainty the decision-makers generally err on the safe side and adopt a conservative standard, opting for — say — 6 kBq/km^2 of caesium-137 in the soil rather than 60 kBq/km^2. This is the approach which led to so much social upheaval after the Chernobyl accident.

Risks in their totality cannot be avoided — only traded. Specific risks can be reduced—but only through what risk theorists call "risk transference".

In the Chernobyl case, the excessive focus on radiological safety in isolation has meant that hundreds of thousands of people had to be displaced, the consequent risk being far greater and more real than the "hypothetical" calculated excess risk due to radiation exposure.

Regrettably, the international scientific community has not stated clearly that much of the activity associated with the countermeasures taken after the Chernobyl accident has been counter-productive and that the risks arising from potential radiation exposure are demonstrably smaller than those due to the unnecessary displacement of populations.

S. LYASHCHENKO (Ukraine): In many parts of Ukraine, owing to the difficult economic situation countermeasures designed to lower the levels of radionuclide contamination in agricultural produce have not been introduced and the contamination levels have even risen (by 25–30% between 1991 and 1995 in some cases). In order to reverse this trend we should — inter alia — launch a programme for the radioactive cleanup of meat combines and large dairies and not simply rely on the collective farms, the State farms and the individual smallholder.

Also, the recommended maximum radioactivity levels for foodstuffs should be gradually brought into line with those accepted in most other countries.

Y. NISHIWAKI (Austria): I believe that there is a perception gap in the radiation safety field between nuclear engineers and other professionals on one hand and the mass media and the public on the other. In the field of nuclear safety, the International Nuclear Event Scale (INES) seems to be working well as a tool for conveying information to the mass media and the public, and I should like to propose that a similar scale for use in the radiation safety field be devised.

E.V. IVANOV (Russian Federation): It is a pity that this conference does not include a session on the effectiveness of the countermeasures taken and the mistakes made in dealing with the immediate aftermath of the Chernobyl accident. Many mistakes were made, but they have hardly been referred to here — and ignoring such mistakes could lead to mistakes in the planning of future countermeasures.

C. FALCKE (UNIDO): UNIDO, which has been assessing the impact of the Chernobyl accident on the industry of Belarus, has proposed a programme for rebuilding the manufacturing sector in Belarus. The central recommendation made by UNIDO, regarding the establishment of a regional development agency, is being implemented with financial support from the European Union.

A copy of the survey report can be obtained from me at UNIDO — room D1517 (tel. ext. 3634) at the Vienna International Centre.

TOPICAL SESSION 7

Nuclear Safety Remedial Measures

Chairperson	L. HÖGBERG, Sweden
Vice-Chairperson	E. ADAMOV, Russian Federation
Scientific Secretary	L. LEDERMAN, IAEA
Rapporteur	A. BIRKHOFER, Germany

Professor Birkhofer was the chairman of the IAEA/UNDHA International Forum on One Decade after Chernobyl: Nuclear Safety Aspects, held on 1–3 April 1996, and reported directly on the outcome of the Forum, taking into account the results of other ongoing programmes.

SUMMARY AND CONCLUSIONS OF THE INTERNATIONAL FORUM "ONE DECADE AFTER CHERNOBYL: NUCLEAR SAFETY ASPECTS", VIENNA, 1–3 APRIL 1996

Presented by

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1. CAUSES OF THE ACCIDENT

The events which led to the accident in Unit 4 of the Chernobyl nuclear power plant on 26 April 1986 have been investigated by many teams of scientists over the past ten years. Although there are still some gaps in knowledge relating to details of some phenomena involved in the accident, the knowledge acquired in the meantime is sufficient to identify the causes and to take effective measures to prevent a repetition of such an event.

The accident occurred while the power supply of turbogenerator 8 of Chernobyl Unit 4 was being tested under coasting conditions. The aim of the tests was to examine the possibility of extending the time of forced core cooling in the case of a loss of off-site power.

The programme in question was inadequate with respect to safety provisions. The test conditions were characterized by a low power level, increased coolant flow through the core, and slight subcooling of the coolant at the core inlet. These factors proved to have a direct influence on the scale of the effects which occurred during the tests.

Immediately after the accident, the Soviet Union emphasized errors and failures of the personnel as the main cause of the accident. This attitude was reflected in the conclusion of a report presented by the Soviet Union at the IAEA in 1986:

> *"The primary cause of the accident was a most improbable combination of violations of the operating procedures and rules, committed by the personnel of the unit.*
>
> *"The accident assumed catastrophic proportions because the reactor was driven by the personnel to such an impermissible state in which the effect of positive coefficient of reactivity on the power growth was greatly enhanced."*

Nevertheless, the serious technical deficiencies causing the accident were already known at that time in the Soviet Union. Design changes were started immediately after the accident. Later, more detailed investigations were performed on the causes of the accident and the relevant phenomena. These investigations, which also included analyses with more sophisticated computer codes for three dimensional core modelling, yielded more evidence on the design deficiencies and their effects. They finally led to a modified view of the accident's causes, shifting the balance between design causes and operational causes towards design causes.

The results are summarized in the main conclusion of the Russian report to the International Conference on Nuclear Accidents and the Future of Nuclear Power: Lessons of Chernobyl (Paris, 1991). This report states that the accident was physically caused by the coincidence of the following main factors: "the positive void reactivity effect and the deficiencies in the CPS design that resulted in positive reactivity introduction under the conditions, in which the reactor had been put before the accident".

These findings were confirmed by later studies as presented at this Forum. Thus, from today's viewpoint, the main causes of the accident can be summarized as follows:

— Severe deficiencies in the reactor's physical design and in the design of the shutdown facilities;
— High positive void effect during operational conditions with high burnup;
— Positive scram effect under conditions of the reactor before the accident;
— Missing incorporation of the operating reactivity margin (ORM) into reactor protection;
— Lack of safety culture in responsible organizations leading to the inability to remedy important weaknesses, even though they had been known long before the accident;
— An insufficiently reasoned and examined test programme with respect to technical safety;
— Violation of operating procedures;
— Operation and operating equipment requiring too much of the responsible staff;
— Insufficient protection against beyond-design-basis accidents.

1.1. Measures taken immediately after the accident

When the experts who were looking into the causes of the Chernobyl accident and their possible remedies came up with their first findings, they gave the highest priority to organizational measures aimed at ruling out a recurrence of the status of the Chernobyl Unit 4 immediately before the accident. The following measures were promptly implemented:

— It was forbidden to perform any experiments, disable reactor protection systems or install in the main control room any extra controls for reactor equipment;
— Plant personnel were instructed to strictly follow regulations concerning the operating reactivity margin and the coolant/feedwater flow rate ratio;
— Stricter requirements were set with respect to the observance of the prescriptions concerning the restart of the reactor after shutdown;
— The operating staff were ordered to check with the plant designer, the architect engineer and the scientific supervisor any departures from the design documentation;
— Immediately after the accident, all RBMK plants were instructed to implement technical measures with regard to credible accident initiators.

In the following years, the causes of the accident were addressed more systematically by technical changes of plant design.

2. THE SAFETY OF RBMKs

2.1. Fundamental safety issues of existing RBMKs

The original design of existing RBMK plants has raised safety concerns in several areas:

— Design features of the core and the shutdown system relevant for the control of reactivity and essential causes of the Chernobyl accident;
— Design of safety systems of the first generation RBMKs for ensuring core cooling;
— Confinement of radioactive material during accidents;
— Possibility of intolerable consequences after a multiple tube rupture;
— Protection against hazards such as fires and floods, in particular for old RBMKs.

Further concerns relate to:

— Quality of equipment and documentation;
— Function of licensing;
— Conduct of operation and feedback of operating experience.

Some of the concerns regarding the safety design of RBMK reactors might also apply to other reactors designed to earlier standards if no sufficient improvements have been performed in the meantime. The importance of recurrent safety reviews is widely recognized in this regard.

In addition to the deficiencies, the RBMK design also exhibits some favourable safety features, in particular a comparatively large thermal inertia which may be characterized by substantial water inventory and low power density in the core.

2.2. First stage of safety upgrading

There is broad agreement that the original design of the RBMK core and shutdown system had severe deficiencies. This holds for all generations of RBMK plants. Between 1987 and 1991, a first stage of safety upgrading was performed for all RBMK units, addressing the most serious problems in this area:

- The void reactivity effect has been reduced by:
  - installation of 80–90 additional absorbers;
  - increase in operative reactivity margin up to 43–45 manual control rods;
  - fuel enrichment to 2.4%.
- The efficiency of the scram system has been increased by:
  - elimination of water columns;
  - increased number of short bottom control rods driven in the core together with the upper rods after trip signals;
  - increased speed of rod insertion;
  - new fast acting shutdown system ($2\beta_{eff}$ in 2.5 s);
  - additional signals for the control and safety system.
- Organization and operation have been strengthened by:
  - more frequent computation and display of the operative reactivity margin;
  - improved operating rules and procedures.

Progress has also been achieved in further areas such as installation of remote shutdown stations, non-destructive testing, training of personnel (simulator). The status of realization of these measures varies from plant to plant.

2.3. Further safety improvements

There remain issues beyond the scope of the first stage of upgrading which require further attention. These needs largely depend on the different stages of RBMK development.

Regarding the original design of safety systems for assuring core cooling and the confinement of radioactive material during accidents and of the protection against hazards, significant differences are found between the first generation of RBMKs and the second and third generations:

- The first generation of RBMK plants was designed according to safety principles and standards of the 1960s. With the subsequent advance of safety objectives, several original design features, such as the lack of a containment, fall short of current safety requirements. Thus, from today's perspective, the original design features in this area are characterized by large safety deficiencies.
- For the second and third generations of RBMK plants, the design of safety systems and the protection against hazards have been considerably improved.

These improvements are basically in line with the evolution of international safety objectives. However, there remain deficiencies when compared with current standards. A general issue is the partial containment concept, which provides a less complete protection and less conservatism than other current reactor designs.

On the whole, the advances of safety objectives with the development of different RBMK generations must be recognized. Furthermore, there exist backfitting programmes for first generation RBMKs which aim, as far as possible, at meeting current safety objectives. These programmes are technically feasible. When carried out, they will lead to significant improvements, provided that they are carefully reviewed by the regulator.

There is no doubt that significant improvements were achieved regarding the safety deficiencies relevant for the Chernobyl accident. For other safety issues, safety upgrading is under way or planned. The realization of this second stage of upgrading has encountered and still encounters large difficulties. That may be characterized as a major, if not the main, current problem for RBMK safety.

The following two aspects seem most relevant for the slow advances:

— In the 1990s, the new independent States encountered tremendous economic problems, rendering difficult both the necessary hardware and software changes at the plants and the establishment of effective structures and processes required to emphasize safety.
— Western countries focused their assistance and co-operation programmes on WWER technology; apart from the Ignalina plant, western support for RBMK backfits was negligible until recently.

2.4. Remaining problems of RBMKs

General considerations

From a fundamental point of view there is no reason why a graphite moderated light water cooled pressure tube reactor could not be safe. For future reactors of that type, the positive void coefficient could be overcome by appropriate (undermoderated) core design and such reactors could also be designed with a full containment. More discussions would be necessary to understand the adequacy of the design of such reactors with respect to the above mentioned deficiencies.

However, it must be recognized that the safety of existing and eventual future RBMK designs (e.g. Kursk Unit 5) finally depends, in the same way as the safety of any nuclear power plant, on a sound implementation of defence in depth. Efforts to achieve high availability are an element within this strategy, but they are not at all sufficient for assuring safety. This is among the basic lessons to be learned from operating experience with nuclear power plants in general and from the Chernobyl accident in particular.

This means that RBMK safety concepts need to ensure appropriate redundancy, diversity, functional segregation and quality of systems assuring the basic safety function under accident conditions. Issues such as the human factor and the management of operation need to be addressed in a systematic way. Quality assurance, in particular the assurance of the material properties of the pressure tubes, needs due attention. Appropriate precautions must be taken to exclude with extremely high confidence any accident initiator that could jeopardize all levels of defence simultaneously. Multiple tube rupture in an RBMK and vessel rupture in a light water reactor must also be excluded with extremely high confidence in the set of measures required to ensure the necessary quality. This issue applies to all current and future RBMK designs. It requires further investigations and research on possible initiators and propagation mechanisms.

Second and third generations of existing RBMKs

Following the backfitting that was directly related to the causes of the Chernobyl accident, the second and third generation RBMKs basically meet most of the defence in depth objectives applied to modern nuclear power plants. Certainly, deficiencies remain, e.g. with regard to the limitations of partial confinement and the control and protection system. Improvements to the core protection system should be considered in relation to improved core design providing a decreased void reactivity coefficient. Questions such as the remaining possibilities of reactivity accidents need further attention. No fundamental problems have been identified so far in solving these issues. However, it must be recognized that the limitations of the partial confinement will require additional investigations and efforts for accident prevention.

Altogether it can be stated that the analyses performed so far have shown that, from a technical point of view, the known safety deficiencies of second and third generation RBMKs could be overcome in a way broadly consistent with the defence in depth concept. Many of the steps to be taken have been already defined and internationally agreed in principle.

First generation of existing RBMKs

The practicability of backfitting of first generation RBMKs raises further questions in addition to the issues relevant for the second and third generations. There have been significant doubts in western countries about the feasibility and the cost effectiveness of backfits. However, from today's perspective it must be recognized that the existing upgrading programmes address most of the safety concerns.

They include the backfitting of essential safety features such as control and protection systems, emergency core cooling systems and partial confinement. It is evident that they will lead to significant improvements, even if they will not always reproduce the technical solutions implemented in new RBMK plants. Where 'classical' approaches are difficult to implement, they often rely on 'compensating solutions' such as:

- Improved prevention of accident initiators where fully satisfactory control of accidents is not feasible or practical (e.g. in-service inspection, leak monitoring, stress analysis and demonstration of adequate material properties required for application of a leak before break concept for critical components (diameter exceeding 300 mm);
- Implementing accident management procedures, where opportunities are provided by systems to ensure that the safety functions are available and/or by the specific advantages of the RBMK design.

The upgrading programme currently carried out at the Leningrad nuclear power plant is a good example that these programmes are feasible if the resources are available and if safety issues receive due attention.

Plant specific considerations

The upgrading programmes for first generation RBMKs confirm the importance of plant specific considerations. This is consistent with the international experience that, if systematically backfitted over many years, nuclear power plants built to earlier standards may reach safety levels comparable with, and in some areas even higher than, new nuclear power plants of the same type. Furthermore, the status of quality and documentation as well as the conduct of operation can considerably vary from plant to plant.

It is therefore obvious that international discussions on RBMK safety needs a sound basis of plant specific technical considerations. This also applies to the elaboration of priorities of upgrading measures and to initiatives aimed at motivating and facilitating investments in safety.

3. OUTLOOK

The answer to the question 'how safe is safe enough' is changing with increasing operating experience, evolution of technological possibilities and the requirement for safety. Many of the safety concerns related to RBMK plants, in particular to the first generation, are related to the fact that initial safety features which are not in line with current safety objectives were not upgraded.

The objective of a dynamic approach to safety with appropriate upgrading according to changing possibilities and objectives is a very general international safety issue. In 1991, the IAEA conference on The Safety of Nuclear Power: Strategy for the Future, formulated a consensus that "safety standards of older operating plants should be reasonably compliant with current safety objectives". Active commitment to this objective is of prime importance for ensuring an acceptable level of safety for nuclear installations and for increasing public confidence in nuclear energy.

The intentions of the RBMK safety approaches are consistent with these principles. This holds for both the evolution of RBMK safety objectives and the backfitting programmes such as currently under way for the first generation RBMKs. However, there are significant problems with the timely realization of concepts. Improvements are required as follows:

— The stringency and transparency of the process should be improved: safety issues need a high ranking when in conflict with other objectives;
— Necessary safety improvements must be carried out independently from consideration of eventual early decommissioning of plants, on a time-scale to be agreed between the regulatory body and the utilities;
— The financial resources available for maintaining and upgrading safety must be increased: it is of prime importance that a reasonable fraction of revenues from electricity sales is available for maintaining and upgrading the safety of existing RBMKs.

A consistent implementation of a dynamic approach to safety needs a sound technological basis. It is required to carry out systematic safety reviews in order to identify shortfalls and their safety significance with regard to current safety objectives and to identify remedial actions such as backfits of plant systems or 'compensating' solutions.

International co-operation can essentially contribute as follows:

— A more extensive technical co-operation on plant specific evaluation of defence in depth, e.g. within recurrent safety assessments, precursor analyses and evaluation of operating experience, could significantly increase openness and concentrate the attention of all organizations relevant for safety on the most significant problems. Such co-operation would strengthen the dynamic safety approach not only in eastern Europe but also in western countries.
— International co-operation could also help to ensure the allocation of financial resources for improving quality, documentation, safety design and the conduct of operation. Particular possibilities are seen in a more systematic use of synergisms between plant availability and safety and of new modes of industrial co-operation.

4. PARTICULAR PROBLEMS AT CHERNOBYL

Most of the above considerations on RBMK safety also hold for the Chernobyl plant. Nevertheless, the situation at Chernobyl is a particular one, since there exists a range of site specific problems. These problems concern both the safety of the remaining units and the consequences of the accident.

Although there are plans to shut down the Chernobyl reactors in the near future, upgrade programmes that have been agreed internationally should be implemented to ensure safety during their remaining lifetimes.

There are clear indications of the unfavourable effect on the safety of the remaining units of the political pressures to close the plant. Thus, the moratorium declared by the Ukrainian Parliament resulted in:

- delays of further safety upgradings after completion of the first stage of measures;
- a severe loss of motivation on the part of plant personnel and a significant loss of specialists;
- deficiencies in safety culture reflected by a negative trend of safety indicators.

The experience in recent years indicates that until now there are still considerable deficiencies in the treatment of safety significant events and in the feedback of the respective experience.

For the consequences of the accident, concerns focus on the sarcophagus built around the destroyed reactor, on the radioactive material contained inside the sarcophagus and on the radioactive material buried on the site.

4.1. The sarcophagus

The sarcophagus was constructed with great urgency under extremely arduous conditions. The destroyed reactor unit was enclosed and a further release of radioactive material to the environment was largely prevented. The sarcophagus has fulfilled this essential protective function for ten years now. The release of radioactive substances is very limited.

However, the sarcophagus is not a permanent enclosure. Its condition raises several questions of safety. The most important issues are:

- the risk of a release of radioactive dust caused by the possible collapse of the building constructions;
- the consequences of contamination of the environment by water from the sarcophagus;
- the possible recriticality of the masses containing fuel material.

The possible instability of the sarcophagus is a significant problem. The concern is mostly related to the fact that essential supports of the main construction had to be built by remote control without fixings such as welding and bolt connections. As a consequence, there is considerable uncertainty regarding the resistance to potential internal and external impacts. This relates above all to the withstanding of loads due to external burden or impact, such as loads due to wind, snow or earthquake, for example. There is broad agreement that the risk of a partial or total collapse during the initially projected design lifetime of the sarcophagus of about 30 years is not negligible if no countermeasures are taken.

Such an event could lead to a significant release of radioactive substances and to very high radiation exposures within the closer surroundings of the plant. With increasing distance, however, doses decrease very quickly and would be very small at distances above 10–20 km. Even in the worst case of a complete collapse, widespread effects are not to be expected. Nevertheless, the stabilization of the sarcophagus is an issue of high priority.

Water entering the sarcophagus is another significant safety issue. The presence of water stimulates disintegration of fuel masses into dust and degradation of building structures by corrosion, and can increase the reactivity of fuel masses. Regarding the risk of groundwater contamination, the existence of water in the sarcophagus bears some risk in the long term. However, this risk is assumed to be much smaller than that from contact of water with the radioactive material buried in the ground outside the sarcophagus.

Possibilities of recriticality have been widely investigated. It has been found that the sarcophagus is currently safe from a criticality point of view. Nevertheless, it cannot completely be excluded that there exist configurations of fuel masses inside the sarcophagus which could reach a critical state when in contact with water. However, even if this could lead to significant radiation fields inside the sarcophagus, neither large off-site releases nor mechanical effects would have to be apprehended in such an event. The impact on the operating personnel of the other units should also be clarified.

The sarcophagus problem requires increasing research efforts in the development of an adequate design and its implementation in the project of conversion of the sarcophagus into an ecologically safe system.

Another specific issue for the Chernobyl plant is the possible implications for safety of the proximity of the sarcophagus and the destroyed reactor to the adjoining operating Unit 3. The risks are generally assumed to be low; however, the issue needs further investigation.

4.2. Further site specific problems

Further site specific concerns relate to the contamination, in particular to the radioactive material buried at the site. The type and extent of the contamination are well known from measurements. Although the local dose rate is considerably high, most areas are accessible. The provisional depositories of highly radioactive material, such as nuclear fuel ejected out of the reactor during the accident, however, represent an obstacle for construction and reconstruction measures. Furthermore, radioactive substances get into the groundwater there. At present, contamination is still low. In the long term there is, however, a considerable risk, and an orderly disposal of the provisional depositories is absolutely required.

4.3. A step by step approach for site restoration

The knowledge about the significance of the risks related with the sarcophagus is still not satisfactory. However, it is known that some problems tend to increase with time. Stabilization and final reconstruction of the sarcophagus are important issues. The strategy of how to proceed, however, must be based on the fact that the stability of the sarcophagus is only one of several problems at the site which have to be solved and which are highly interconnected.

The required further investigations need a broad basis. The actions financed by the European Commission in this area contribute to achieving this objective.[1] However, programmes such as those financed by the European Commission should integrate more effectively the know-how of the competent organizations of the countries of the former USSR.

Given the scale of the problems to be solved at Chernobyl, it is evident that major long term efforts are needed. The stability of the sarcophagus must be ensured, the destroyed reactor permanently secured, the wastes disposed of and the site reconstructed. This will require substantial resources.

There is broad agreement that these problems call for an integrated approach divided into suitable steps. This approach should be based on realistic targets which take into account the radiological conditions on the site and appropriate safety and waste disposal priorities. It should begin with a stabilization of the existing sarcophagus. This stabilization could significantly reduce the risk of a collapse of the shelter and provide time for a careful reflection and planning of further measures, such as the construction of a new encasement and the waste management (recovery or partial recovery of fuel masses inside the sarcophagus, and disposal of radioactive material buried on the site).

It is obvious that the scale of these needs makes the issue for the Chernobyl plant different from that for other RBMK sites. The Chernobyl plant requires a broader approach within the national programmes of Ukraine and within international co-operation programmes. This approach needs to address the socio-

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[1] The representative of the European Commission declared that an agreement has been reached between the Ukrainian authorities and the European Commission on technical measures aimed at the stabilization of the sarcophagus and the construction of a new encasement.

economic situation of the affected population, the dependence of Ukraine in the RBMK sector on imports of equipment, fuel and technology, and the need for a careful follow-up of the impacts of the accident. It must take into account the economic problems and the long term need for substantial human and financial resources for site restoration.

DISCUSSION ON BACKGROUND PAPER 7

D.T.Y. CHEN (Switzerland): With regard to the three remaining reactors at the Chernobyl NPP, I should like to know whether the problem of the positive void coefficient has been resolved.

A. BIRKHOFER (Germany, Rapporteur): The void coefficient has been reduced to a value less than one beta. It is still slightly positive, but even the emptying of fuel channels would now not lead to super-prompt criticality — the shutdown system would be able to cope with the reactivity increase.

D.T.Y. CHEN (Switzerland): Could someone from Ukraine say something about the future of those reactors?

P. PAVLOVSKY (Ukraine): As Prime Minister Marchuk of Ukraine said on the first day of the Conference, the question of shutting down those reactors — that is to say, of closing the Chernobyl NPP — is a political question. Ukraine is ready to close it at an early date, as called for by the Group of 7, but early closure would cost Ukraine some US $4400 million — and the amounts being offered to Ukraine in return for early closure fall far short of that.

If the idea of closure at an early date were dropped, Ukraine itself could in the next century, with the help of revenues earned by the Chernobyl NPP, resolve the problems associated with its ultimate closure.

V. KUCHAR (Ukraine): Ukraine's nuclear regulatory body, which monitors the safety of operating RBMKs, is calling for safety improvements in the light of new information, data and requirements.

The Ukrainian authorities are currently examining plans for closing the Chernobyl NPP which do not entail compliance with new general safety requirements during the period until closure. If the question of reconstructing the Chernobyl NPP arises, we shall proceed on the basis of the safety requirements generally accepted at that time.

P. KAYSER (Luxembourg): Would it not be better to use funds made available by the Group of 7 in upgrading the safety of all 15 RBMKs still in operation rather than as compensation for the closure of the Chernobyl NPP?

A. BIRKHOFER (Germany, Rapporteur): That is essentially a political matter.

All RBMKs need safety upgrading regardless of whether they are to be shut down in the near future or the not-so-near future, and their safety upgrading poses problems due to the fact that RBMK technology differs considerably from the technology of western power reactors and a dialogue between RBMK designers and western reactor experts got under way only recently.

E. ADAMOV (Russian Federation, Vice-Chairperson): In that connection I would mention that the cost of upgrading the safety of Units 1 and 3 at Chernobyl to acceptable levels was last year estimated to be about US $350 million. The cost of upgrading the safety of all 15 operating RBMKs would therefore be about US $2000 million, but that is less by a factor of two than the estimated costs which would be involved in closing the Chernobyl NPP.

F.M. MALTINI (European Bank for Reconstruction and Development): With regard to the point raised by Mr. Kayser, I would mention that EBRD has a Nuclear Safety Account whose purpose is to provide — through grants — equipment for short-term safety upgrades to Soviet-designed reactors of the WWER-440/230 and the RBMK type. The current approved budget exceeds ECU 250 million. Projects supported from the Account are at present under way at five nuclear power plants — Kozloduy (Bulgaria); Ignalina (Lithuania); and Kola, Novovoronezh and Leningrad (Russia).

All the project agreements exclude plant life extension as one of the objectives. In the case of the Ignalina NPP, the project agreement provides for the shutdown of Unit 1 if an in-depth EBRD-financed safety assessment justifies the Lithuanian regulatory body's requesting an end to the unit's operation.

As regards the Chernobyl NPP, the administrators of the Nuclear Safety Account are holding discussions with the Ukrainian authorities on a project (to an earmarked value of ECU 100 million) which foresees, inter alia, short-term upgrades to Unit 3 (with the provision of diagnostic, reactivity control and radiation and hydrogen monitoring equipment and spare parts) and the construction of a storage facility for some 26 000 spent fuel assemblies and of a treatment plant for low- and intermediate-level liquid waste.

Y. NISHIWAKI (Austria): In the discussion of safety upgrading, little thought seems to be given to the human factor. In this connection, I would mention that in a report from the Russian Federation which I saw recently it was stated that the frequency of operational events at nuclear power plants was highest during daytime (between 11 a.m. and 5 p.m.), which is when one would expect plant personnel to be most wide-awake.

E. ADAMOV (Russian Federation, Vice-Chairperson): The higher frequency of operational events during daytime is probably due to the fact that most overhauling and maintenance work — which can give rise to operational events — is done during daytime.

L. HÖGBERG (Sweden, Chairperson): I would add that human factor concerns are certainly being addressed in the European Union consortium programmes, which are also taking into account the organizational changes under way in the nuclear sector of the countries where RBMKs are in operation.

Human factor considerations are receiving as much attention as technical considerations in the joint Swedish–Lithuanian programme of co-operation in the nuclear safety area.

R.M. CHATTERJEE (Canada): Does groundwater contamination occur in the Chernobyl area only from within the sarcophagus?

V.M. SHESTOPALOV (Ukraine): No. In fact, the highest groundwater contamination levels have been found not right by the sarcophagus, but under temporary radioactive waste storage points — of which there are some 800 around the Chernobyl NPP. The strontium-90 contamination level is 120 000 Bq/L in groundwater under the area where material from the "red forest" is being kept.

As regards the Chernobyl NPP itself, special countermeasures to prevent groundwater contamination are at present unnecessary. Radiation and chemical monitoring of the groundwater is being carried out, in which connection it is worth noting that the rates of radionuclide migration in the groundwater are extremely low.

A. ALONSO (Spain): In the penultimate paragraph of the Background Paper, reference is made to "the recovery or partial recovery of fuel masses inside the sarcophagus". I should like to hear more about this idea.

V. KUCHAR (Ukraine): At present, the sophisticated robotic equipment necessary for such a task does not exist, and we should like to see work on its development starting now. We should also like to see international participation in such work.

P. HILLE (Austria): I understand that no probabilistic safety assessments (PSAs) have been carried out for the 15 RBMKs in operation and wonder why not. If you cannot demonstrate that the probability of a major radioactive release is well below 10^{-3} (per reactor and year) and you want to run the 15 RBMKs for, say, a further 15 years, you are faced with a risk of 1/5, which I do not consider to be reasonable.

L. HÖGBERG (Sweden, Chairperson): A PSA has been carried out for the Ignalina NPP within the framework of the European Union consortium project, and the conclusion is that with safety improvements it should be possible to reduce the probability of substantial core damage to about 10^{-4}, which is in line with the target for existing western reactors.

This PSA is one of the major foundations for the programme of safety improvements at the Ignalina NPP.

There are plans for PSAs to be carried out for other RBMKs, and information in this connection is contained in a report which can be obtained from the Swedish Nuclear Power Inspectorate.

S. LATEK (Poland): It has been suggested that the RBMKs still in operation should not be shut down for good in the near future because that would infringe the human rights of people living in Ukraine whose livelihood depends on the continuing operation of those reactors. I should like to point out that their continuing operation could lead to infringements of the human rights of people living in other countries.

A. BIRKHOFER (Germany, Rapporteur): Those factors leading to the Chernobyl accident which were connected with the physics of RBMKs have been eliminated, so that super-prompt criticality should no longer be able to occur in RBMKs — a very positive point. Also, the safety characteristics of RBMKs have been improved, and further improvements are planned. Whether all of that will be sufficient is not yet known; some possible accident scenarios have still to be calculated.

W.P.S. LEPECKI (Brazil): Could the review mechanism foreseen in the Convention on Nuclear Safety serve as a basis for the international evaluation of safety at the Chernobyl NPP?

A. BIRKHOFER (Germany, Rapporteur): Let me first say that, in my view, nuclear safety should remain a national responsibility; the main purpose of international co-operation in the nuclear safety area should be to help national regulatory bodies do their job properly.

I hope that, when the Convention on Nuclear Safety enters into force, it will trigger a self-education process; its aims could not be achieved by the creation of an international nuclear safety inspectorate. At the same time, I believe that international peer reviews are necessary, but not as a substitute for detailed safety analyses by national authorities.

E. ADAMOV (Russian Federation, Vice-Chairperson): In response to the widely held view that RBMKs should be shut down for good sooner rather than later, I should like to present a slide (Fig. 1) showing the main findings of a number of RBMK safety reviews. It will be seen that these findings do not suggest that there is any great urgency about shutting down RBMKs for good. In this connection, I would recall that in the United Kingdom there are still some power reactors without a full containment and that Canadian power reactors have a positive void coefficient.

- Most recommendations of international experts have supported the measures envisaged by national programmes.
- All RBMK units have undergone improvements with regard to the peculiarities of the Chernobyl accident.
- Safety problems of RBMK plants are akin to those faced by western NPPs of the same age.
- Not a single insoluble safety problem has been identified for the comprehensively studied units of the 3rd generation.
- Units of the 2nd generation can be brought to the safety level of 3rd generation units.
- The safety of the 1st generation units can be significantly enhanced by retrofitting.
- Rupture of one fuel channel cannot lead to breaks in adjacent channels, and no accident sequence has as yet been reliably identified, which could cause independent breaks of several fuel channels.
- ASSET missions have not identified any operational problem which would prevent the current operation of the four inspected RBMK plants.

FIG. 1. Main findings of international projects for RBMK safety reviews.

Also, further to what was said just now by Mr. Pavlovsky from Ukraine, I should like to present a slide (Fig. 2) showing estimates which we have made of the cost of shutting down RBMKs for good while they still have substantial service lives ahead of them.

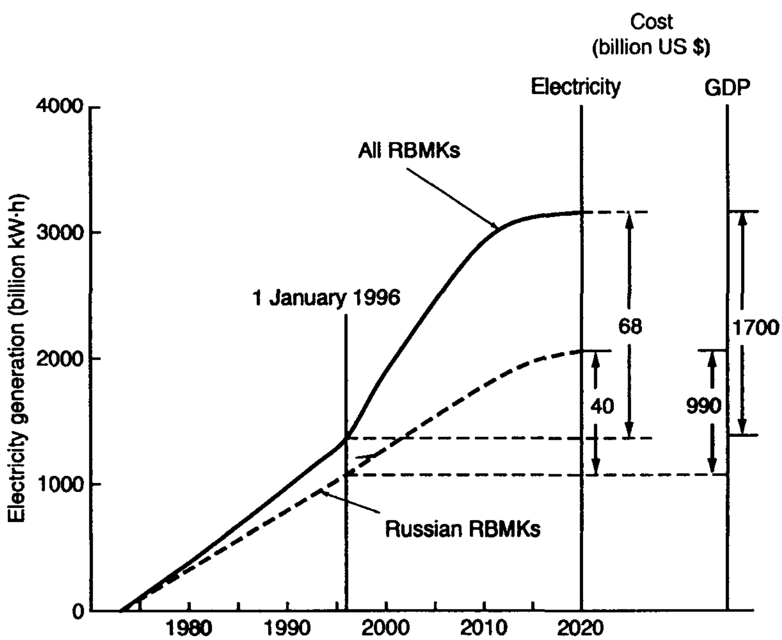

FIG. 2. Total electricity generation at RBMKs, its cost and corresponding GDP.

TOPICAL SESSION 8

The Consequences in Perspective: Prognosis for the Future

Chairperson	K. DUNCAN, United Kingdom
Vice-Chairperson	I. PONOMARENKO, Ukraine
Scientific Secretary	T. McKENNA, IAEA
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THE CHERNOBYL ACCIDENT: THE CONSEQUENCES IN PERSPECTIVE

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Abstract

THE CHERNOBYL ACCIDENT: THE CONSEQUENCES IN PERSPECTIVE.

The paper summarizes the consequences of the Chernobyl accident in order to provide a factual basis for future policy decisions. There are two main issues: What actions can be taken to limit the health effects of the accident? And: What risk is still posed by the remains of the reactor in the sarcophagus? Assessing the health effects of radiation exposure due to the accident is very difficult. The doses received as a result of the accident are not well known and the complex relation between dose received and cancer induction is still not well understood. As a result, projections of future numbers of extra cancer cases depend on a number of assumptions and are at best crude estimates. Epidemiological investigations to detect health effects in populations, as opposed to effects in individuals, are complex and extremely difficult to conduct. It is difficult to find appropriate control groups for comparative purposes and to distinguish the influence of the studies themselves on the results. In addition, there has been a general deterioration in public health in the countries of the former Soviet Union since 1987. This general trend towards poorer health has been misinterpreted and misrepresented as being due to the Chernobyl accident. It has been asserted that up to tens of thousands of people 'have already died', implying that they were victims of the Chernobyl

accident. However, the total death rate in 1990–1992 among 'liquidators' (emergency and recovery workers) did not exceed that for the corresponding age group in the Russian Federation as a whole. The only health effects to date that are attributable to radiation exposure due to the accident are an increase in the incidence of thyroid cancer in children, and various health effects among the initial responders; psychological effects are unrelated to radiation but are attributable to the accident and the countermeasures taken and the consequent disruption and distress caused. The increase in the incidence of childhood thyroid cancer has been dramatic and, if it persists in members of the age group affected as they grow older over the coming decades, it may result in up to several thousand excess cases of thyroid cancer. The number of fatalities would be much lower than this, since treatment should be 90–95% successful if the thyroid cancer is diagnosed early. The affected people should therefore continue to be closely monitored throughout their lives. There have been local reports, not yet confirmed by any international group, of small increases in the general rates of other cancers and other health problems in the affected countries. However, any such increases may result from factors unrelated to radiation exposure due to the accident. On the basis of the estimated doses resulting from the accident, any attributable increase in all cancers would not be statistically discernible from the normally occurring 'background' rate of cancer. Increases in leukaemia and thyroid cancer among the most highly exposed groups (liquidators and evacuees) may in principle be detectable in the future. However, before any such increases could be attributable to radiation exposure due to the Chernobyl accident, they would have to be carefully distinguished from upward trends in cancer incidence that began before the accident. The psychological effects of the accident and of the continuing countermeasures taken are clearly important and, while not directly due to radiation exposure, are likely to be among the most important legacies of the accident. The psychological effects are difficult to distinguish and to quantify, however. What can be done now to limit the health impact of the accident in the future? For much of the area contaminated at the time of the accident, radiation dose rates are presently within the range of dose rates due to the natural background levels of radiation found in Europe. As a result, it is unlikely that *future exposure to radiation* as a result of living in these areas will lead to any detectable increase in the incidence of cancers. Any measures intended to reduce future doses further should therefore be carefully evaluated for their effectiveness, and their expected benefits should be weighed against their probable economic and psychological costs. There are two groups of people who would clearly benefit from careful medical monitoring in the future: those children with an elevated probability of incurring thyroid cancer, and the most highly exposed among the liquidators. As for whether the destroyed reactor still poses a threat: any high radiation dose rates as a result of a potential collapse of the sarcophagus now enclosing the reactor's remains would be confined to the plant's immediate vicinity. However, more importantly, a collapse of the sarcophagus could have implications for nuclear safety at the operating Unit 3. In addition, the sarcophagus and material dumped in its vicinity form presently an unconfined source of a large amount of radioactive material which could eventually represent a contamination hazard for the local groundwater. These issues require further study. The question in conclusion is: *What policies and measures can now be developed by the most affected countries for the public and for the Chernobyl plant to take into account both the present radiological risk and the economic, social and psychological impacts of the accident and to yield the greatest benefit?*

1. INTRODUCTION

The accident at Chernobyl in Ukraine on 26 April 1986 was the world's worst nuclear accident. It led to widespread radioactive contamination in Belarus, Ukraine and the Russian Federation, and caused difficulties elsewhere in Europe. Over the last ten years, the patterns and levels of deposition of radioactive materials, except for the very short lived radioisotopes, have been extensively studied and documented, so that it is now possible to make refined estimates of the long term individual and population doses and to evaluate more accurately the actual and potential radiological health effects of the contamination.

The Chernobyl accident occurred at a time of major change in the former USSR. The period since the accident coincided with the 'post-perestroika' (restructuring) period from 1987, following economic restructuring, and with a sharp fall in economic indices on a scale such as is usually associated with countries at war. *Over this period the life expectancy of Russian men fell by about six years.*

2. CONSEQUENCES OF THE ACCIDENT, 1986–1995

2.1. General background

The primary health concern following a major radiological accident is that there may be an increase in the incidence of cancer among the affected population. It is therefore not surprising that many estimates have been made of the total number of cancers and of deaths due to cancer to be expected as a result of the Chernobyl accident. In late 1986 and early 1987, experts' forecasts of the total number of fatal cancers to be expected due to the accident varied from a few thousand to 30 000 in total. This wide variation occurred because the calculations were based on various assumptions concerning the affected populations, the collective dose, the dose coefficient for fatal cancers and other factors. None of these factors was properly understood or commonly agreed upon, and all the underlying assumptions have been revised over time.

The largest estimate of projected fatal cancers results from the simplistic theoretical calculation of multiplying the collective dose, presumed in theory to have been incurred by the population of the entire northern hemisphere, by the dose coefficient for fatal cancers. Such a simplistic calculation would lead to a projection of a total of about 30 000 excess fatal cancer cases in addition to the 800 million naturally occurring cancer cases expected in the same population over the next 60 years. This represents of the order of one extra cancer case for each 10 000 naturally occurring cases. However, most of these excess cancer cases would be the result of low doses for which there is no action that can be taken to reduce the risk.

The variation in these forecasts came as no surprise to scientists, but the uncertainty was not accepted either by the decision makers or by the affected populations [1]. The citation of these projections without any understanding of the assumptions or uncertainties, the time frame, the size of the population concerned and the number of normally occurring fatal cancers was misleading.

Any estimate of the total number of fatal cancers resulting from the accident will be at best crude and will depend on the assumptions made. Such forecasts of numbers should not be accorded the status of scientific objectivity.

It is emphasized that the dose to the affected populations will be delivered over a long period, and the total committed dose over 70 years (representing the standard human lifespan) is the important quantity. This dose is not delivered at a uniform rate; most of it is incurred in the first ten years. The largest part of the dose (50–70%) due to living in the contaminated regions has already been received, and the remainder (30–50%) will be received over the next 60 years.

The largest part of the radiation dose from the accident has already been received. For doses already received, no remedial measures can now be adopted to reduce the increased risk of cancer (except possibly for thyroid cancer).

In European countries, the normal everyday exposure to radiation due to the natural radiation background gives rise to doses in the range of 1.7–7.0 mSv per year, i.e. about 120–500 mSv over a 70 year lifespan. Figure 1 shows the average measured lifetime dose due to radiation from the natural background in several European countries [2] in comparison with the estimated average lifetime dose due to the Chernobyl accident, for areas with three different levels of caesium ground contamination from the accident: low (37–185 kBq/m^2), medium (185–555 kBq/m^2) and high (555–1480 kBq/m^2). The estimated dose due to the accident shown in Fig. 1 is that expected to be received by someone living in these regions for the next 60 years. This includes the dose due to external exposure from ground contamination and the dose from ingestion of contaminated foodstuffs.

These areas are examined because the countries affected continue to take protective measures in areas with these levels of contamination. The protective measures have changed over time and have been different in each country, ranging from mandatory evacuation to various institutional controls. Compensatory measures were also taken, including monetary payments and the granting of social privileges.

For these areas, the future doses due to the current contamination levels resulting from the accident are within the range of doses due to the natural background found in uncontaminated areas of Europe. There have been extensive

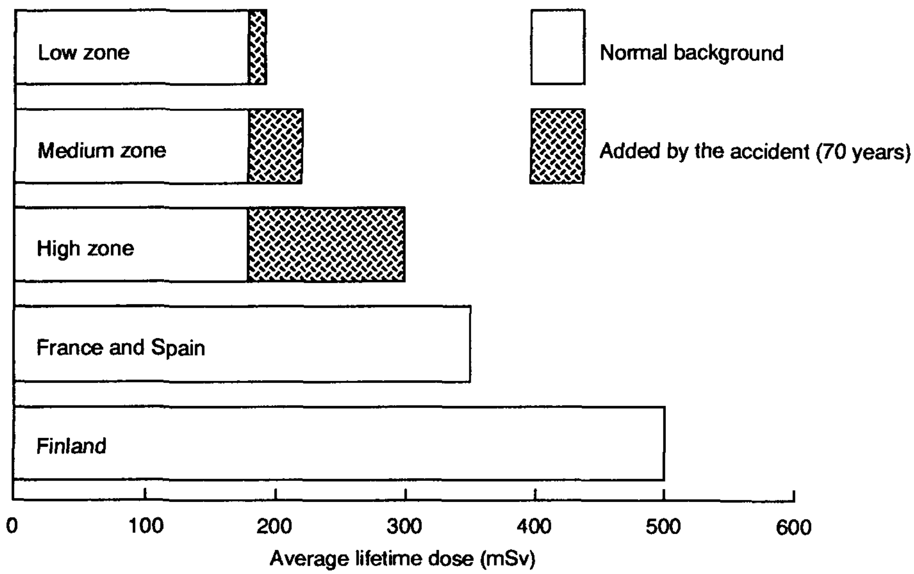

FIG. 1. Average lifetime radiation dose due to natural background radiation for various European countries and doses from the contamination due to the Chernobyl accident in various radiation zones.

investigations of areas with naturally occurring high background radiation levels to see whether any increased incidence of cancer is associated with an increase in exposure. No such increase has been demonstrated. Consequently, no increase in cancer incidence is expected to be detected in the populations living in these areas as a result of doses due to the current ground contamination due to the accident. It may, however, be possible to detect increases in specific cancers (e.g. cancer of the thyroid gland) resulting from doses received during the early phases after the accident.

For much of the area contaminated by the accident, current dose rates (including the additional dose due to the accident) are within the range of dose rates due to the natural background found in areas of Europe uncontaminated by the accident. As a result, it is unlikely that *future exposure* due to contamination from the accident will lead to a detectable increase in cancer incidence. Any proposed remedial measures intended to reduce this dose further should therefore be carefully evaluated for their effectiveness and their probable economic and psychological impact.

2.2. Demonstrated health effects

Demonstrated health effects of the accident are examined for three groups: (1) initial responders; (2) liquidators (i.e. other emergency and recovery workers); and members of the public evacuated from, and those still living in, contaminated areas; and (3) persons suffering from thyroid cancer. These three groups of exposed individuals have received the highest doses and are those who have been most studied.

Several different terms are used for cancers. Thyroid cancer and leukaemia receive special attention because their incidence rates are believed to be especially sensitive to radiation exposure resulting from a nuclear accident. Solid cancer is the term used for all cancers except leukaemia. This distinction is made because any increases in the rate of leukaemia (non-solid cancers) would be expected to be seen much sooner after exposure (of the order of 10 years latency period) than would solid cancers. 'All cancers' means simply the sum total of all cancers, solid and leukaemia, in a population. The term 'natural' or 'normal' cancer in the present context means cancers not resulting from the increased exposure to radiation due to the Chernobyl accident.

In assessing the health effects of radiation exposure, two different approaches are normally taken. In the first approach, the doses to the whole body and various sensitive organs (e.g. the thyroid gland) are estimated for the entire group of concern and the number of cancers is calculated, assumptions being made about the effectiveness of the radiation to induce various cancers. This approach, which permits the number of cancers to be predicted, requires information on the dose to each organ and to the whole body for each group at risk. In addition, the relationship between dose and excess incidence of cancer must be known. However, the patterns of contamination were highly variable, resulting in wide variations in individual doses. Furthermore, the relationship between dose and cancer incidence is not known with accuracy and is still being debated.

In the second approach, epidemiological investigations are conducted to determine whether an increase in health effects among a population can be detected. It is extremely difficult to conduct reliable epidemiological investigations under the prevailing circumstances in the three countries. One difficulty is in finding suitable control groups of unexposed people for comparative purposes who are similar, not only in age, but also in geographical distribution and social structure. Also, the exposed groups are being more closely monitored for health effects, so that morbidity data (i.e. data on disease) may be affected by heightened awareness of symptoms and better reporting.

The difficulties are exacerbated in looking not only for health effects but also for causal relationships. Many of those affected by the accident have been subjected to great hardship and stress quite apart from their exposure to radiation. Such hardship, directly or indirectly, can cause significant harm to health.

There is typically a latency period of 10–30 years or more between exposure to radiation and the onset of solid cancers. It would therefore be premature to draw any final conclusions on the basis of epidemiological investigations made up to now, only ten years since the accident.

2.2.1. Demonstrated health effects among the initial responders

The highest doses were received by the Chernobyl plant staff and fire fighters during the initial response to the accident. Among this group there were 30 deaths, two of which occurred within 24 hours of the accident. The only cases of acute (i.e. early) radiation sickness seen as a result of the accident were among the initial responders. Of the initial responders, 237 were treated for symptoms of radiation sickness. Of this group, 28 died of radiation injuries within weeks of the accident (Table I). Subsequently, 14 more of these original 237 patients died, in addition to the 28 early deaths due to radiation exposure. According to Background Paper 1, however, the listed causes of these 14 deaths were not necessarily due to radiation exposure.

Acute radiation sickness and early deaths occurred only among the initial responders to the accident.

TABLE I. CASES OF INITIAL RESPONDERS TO THE CHERNOBYL ACCIDENT WHO SUFFERED HIGH DOSES AND WERE TREATED IN SPECIALIZED HOSPITALS

Estimated dose (Gy)	Number of patients	Number of early deaths
6–16	21	20
4–6	21	7
2–4	55	1
1–2	140	0

2.2.2. Demonstrated health effects (other than thyroid cancers) among liquidators and the public

The term liquidators refers to persons who were engaged in containing the accident, as well as the large numbers of people who were subsequently brought into the 30 km 'exclusion zone' to respond to the accident and to reduce radiation levels.

The doses and the health records of the liquidators were initially recorded in the All-Union Dose Registry (AUDR) of exposed individuals, which was started in May 1986. This registry was replaced in 1992 by national registries for Ukraine, Belarus and the Russian Federation. In 1994 these registries held data on 350 000, 136 000 and 159 000 liquidators, respectively. The Russian National Medical Dosimetric Registry (RNMDR) in 1994 contained data on 99 000 individuals with documented dose and health records [3]. It is from this registry that the most detailed morbidity (disease) and mortality data are available.

There are several reasons to doubt the accuracy of these registries. One is that the right to compensation has been an incentive for claiming liquidator status, and unsubstantiated claims have to some extent been accepted by the authorities. In Ukraine, for example, it is estimated that between 50 000 and 150 000 persons have been so registered on false premises.

Approximately 200 000 liquidators worked in 1986–1987, when the exposures were most significant. A reasonable estimate for the average dose to those in this group is 100 mSv. For those who worked in the 30 km zone during the first year, the reported average dose is 165 mSv. This estimate should be considered crude because of the improvised methods used to estimate doses to the liquidators during the initial phase of the response. In addition, these dose values refer to external dose only. The early liquidators are also likely to have received internal doses from ingestion and inhalation of radionuclides. For the 375 persons examined, the mean internal dose was estimated to be 64 mSv [4].

The overall incidence of disease among the liquidators in 1992 was reported to be roughly the same as that for the corresponding age group in Russia as a whole [5]. There was, however, a marked excess of some diseases, including diseases of the blood and blood forming organs, the nervous system and sensory organs, and the circulatory system [3]. The authors noted that other unfavourable factors such as emotional stress have had effects on the health of liquidators.

There was no increase in the incidence of total cancers among liquidators compared with the general population in Belarus. In Russia, a small but marginally statistically significant increase in the incidence of total cancers was noted. In Ukraine, a 20% increase in the incidence of all cancers was observed, as well as increases in the incidence of several specific cancer types. There was no significant difference in leukaemia incidence in Belarus or Russia; however, in Ukraine, a significant increase was reported.

These results must be treated with caution, however, since the cases have not yet been verified, and the increases may reflect the increased surveillance of the liquidators and under-registration of cancers occurring before the accident in countries where no systematic cancer registry existed at the time [6].

An attempt has been made to correlate excess morbidity with radiation dose, and to derive a risk factor per unit dose. Since the positive correlations that resulted are largely for diseases that are not associated with radiation exposure, and because of the difficulty of accounting for other factors, the causality of the correlations is questionable.

It has been periodically asserted that a number amounting to up to tens of thousands of liquidators (the figure varies) ''have already died'', implying that they were victims of the Chernobyl accident. In fact, the total death rate among liquidators (1990–1992) did not exceed that for the corresponding age group in the entire Russian Federation. The main cause of death for the liquidators (as well as for the corresponding general population) was 'injuries and poisoning', which accounted for about 54%. This was followed by cardiovascular conditions (20%) and solid cancers (about 15%) [5].

It is estimated that some 135 000 people were initially evacuated from the 30 km zone and some other highly contaminated regions. These people probably received the highest doses among the general population. The average individual dose among this group has been estimated to be about 10 mSv. This would give rise to a low collective dose that is unlikely to lead to an observable increase in cancer incidence. However, this does not hold true for cancer of the thyroid, which is discussed in the following.

In medical field studies [7] that were conducted in the latter part of 1990, data from seven contaminated (over 555 kBq/m^2) settlements were compared with data from six uncontaminated settlements. In all, 1356 people from selected age groups were comprehensively examined by international medical teams. The general conclusion reached was that there were significant disorders unrelated to radiation exposure whose extent was similar in both the contaminated and the uncontaminated settlements, but there were no disorders that could be attributed directly to radiation exposure.

Later studies found no increase in the incidence of total cancers in Ukraine. In Russia and Belarus, a marginally statistically significant increase in all cancer mortality was noted. Again, because of increased awareness of the consequences of the accident, and because of the more intensive medical follow-up of populations living in contaminated regions, these findings must be interpreted with caution. Further analyses are needed to confirm or refute this finding.

Studies of the survivors of the atomic bombing of Japan and of other highly exposed populations have shown that increased leukaemia incidence rates are the most sensitive indicator of health effects resulting from exposure of the whole body. Studies of childhood leukaemia in Belarus [8] found no detectable increase in leukaemia rates in the period 1982–1994. The authors noted that ''where there are no observable increases of childhood leukaemia, it is highly implausible that striking rises of other health defects are due to radiation. In view of the high thyroid doses, effects on the thyroid are of course a separate matter''.

The available statistics for the countries of the former USSR reflect an increase over the period since the Chernobyl accident in the total number of deaths due to cancer. A study of the time trends of cancer incidence in the most contaminated regions of Ukraine before and after the accident indicates an increase similar to that in the uncontaminated regions (Fig. 2) of Ukraine [6]. If radiation exposure due to the accident were the cause of this increase, the increase would be expected to be greater in the contaminated areas than in the uncontaminated areas, which is not the case.

Nevertheless, owing to the long latency period for solid cancers, it is necessary to continue to monitor the exposed population, especially those who received the highest doses. Prisyazhniuk et al. [6] studied the time trends of cancer incidence in the most contaminated regions of Ukraine and concluded: "Nine years after the Chernobyl accident, there is no scientific evidence for an excess of incidence of malignant tumours, except for thyroid cancer, attributed to the radiation factor, even in the most contaminated areas."

Small but significant increases in the rates of some cancers and other health problems have been reported among the liquidators and among the most exposed members of the public. However, except for thyroid cancer, these apparent increases may be due to the improved medical observation of these groups or to other factors not related to radiation exposure due to the accident.

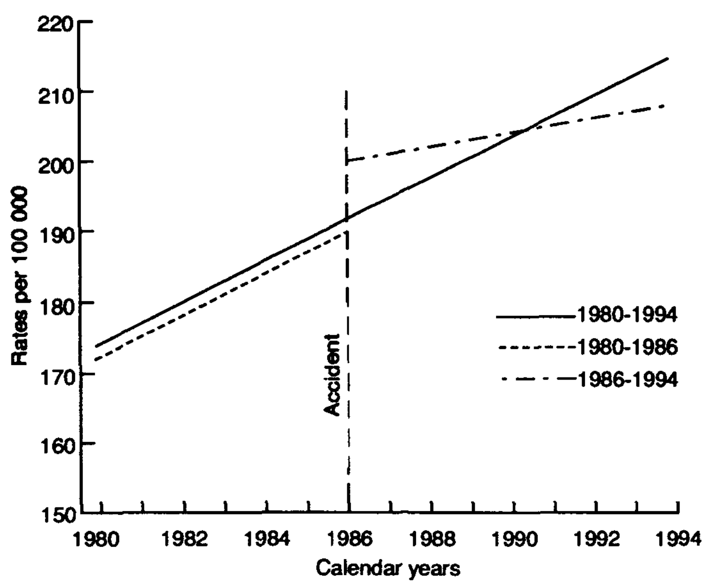

FIG. 2. Regression analysis of age adjusted rates of cancer incidence in 'strict control' areas (males and females) for the periods 1980–1985, 1986–1994, 1980–1994 [6].

Great concern was expressed immediately after the accident for newborn children of women who were pregnant at the time of the accident. The only reported effect in such cases is a slight, statistically non-significant, rise in the incidence of mental retardation in children in the affected areas. The results are difficult to interpret and require further investigation. For example, the increase in the number of reported cases could have been due in part to better surveillance.

There may have been a slight rise in the incidence of mental retardation among children exposed in utero. However, no clear interpretation of the figures is yet possible and further study is required.

2.2.3. The present situation for thyroid cancer

Large quantities of radioactive iodine were released by the accident. Iodine that is inhaled or ingested concentrates in the thyroid gland, giving rise to thyroid doses that are much higher than the doses to other parts of the body. The important forms of radioactive iodine are short lived, and iodine exposure is therefore important only in the first weeks after an accident. Young people who were children at the time of the accident are especially vulnerable to exposure due to radioiodine.

The thyroid doses for children that were reported in 1986–1987, on the basis of direct measurements of iodine content in the thyroid, clearly warranted this concern. However, many thyroid dose estimates were less accurate because they were based on air sampling and comparisons with the ground deposition of radiocaesium. Nevertheless, it is clear that the number of children exposed to radioiodine and their levels of exposure were alarmingly high.

It is estimated on the basis of direct measurements performed on the evacuees and the evaluations made by dose reconstruction [9–11] that the mean representative doses for the affected children were:

— for Ukraine, ~100 mGy for children less than 3 years old and ~20 mGy for teenagers;
— for Belarus (Gomel and Mogilev), around 700 mGy;
— for Russia, around 400 mGy for the most contaminated areas.

While the accuracy of the estimated thyroid doses may be questionable, it is clear that doses were high in some areas, especially for young children. There were wide variations in the distribution of thyroid doses in the same area. Specific countermeasures to reduce thyroid doses, such as the administration of stable iodine and the interdiction of contaminated foodstuffs, were effected poorly or not at all. In some areas 100 km or more from Chernobyl, such as the southern parts of Belarus and the Bryansk region in Russia, information on the accident was scarce, no instructions or recommendations were given, and no alternative food was supplied.

By 1992, an increase in the incidence of thyroid cancer among children in Belarus had been reported, which was confirmed by teams of European specialists [12–14]. When these data were first published, they met with some scepticism [15, 16]. However, the increase in the incidence of thyroid cancer was corroborated by new cases in the following years, at an increasing rate in Belarus, and equivalent findings in Ukraine and Russia. A regular and incontrovertible increase in the absolute number of thyroid cancers has been observed over the years since 1992.

Table II shows the increase in total numbers of thyroid cancers detected and the corresponding rates, in Belarus and Ukraine and in the most contaminated regions, i.e. Gomel in Belarus, the northern regions in Ukraine and Bryansk in Russia. Figure 3 shows the numbers of thyroid cancers detected in Ukraine each year over the period 1986–1993. In the more contaminated Chernigov oblast the increase was 35-fold and in the Zhitomir oblast 16-fold. In the Bryansk district in Russia the excess appeared later.

It is thus clear that there has been a significant increase in the incidence of carcinoma of the thyroid in children. It must be assumed that this is due to the Chernobyl accident. There has also been an increase in the incidence of thyroid cancer in adults in Belarus and Ukraine.

TABLE II. INCIDENCE OF CHILDHOOD THYROID CANCER (0–14 YEARS) IN BELARUS AND UKRAINE AND IN THE MOST CONTAMINATED AREAS OF BELARUS (GOMEL REGION), UKRAINE (NORTHERN REGIONS) AND RUSSIA (BRYANSK REGION) (FROM REF. [17])

Area	Absolute numbers		Corresponding incidence per million per year[a]	
	1981–1985	1986–1994	1981–1985	1991–1994
All Belarus	3	333	0.3	30.6
Gomel	1	164	0.5	96.4
All Ukraine	25	209	0.5	3.4
Northern Ukraine	1	118	0.1	11.5
Bryansk and Kaluga, Russia	0	23	0	10.0

[a] Incidence is given for the last period of observation, 1991–1994, while numbers are given for the period starting in 1986 when the accident occurred.

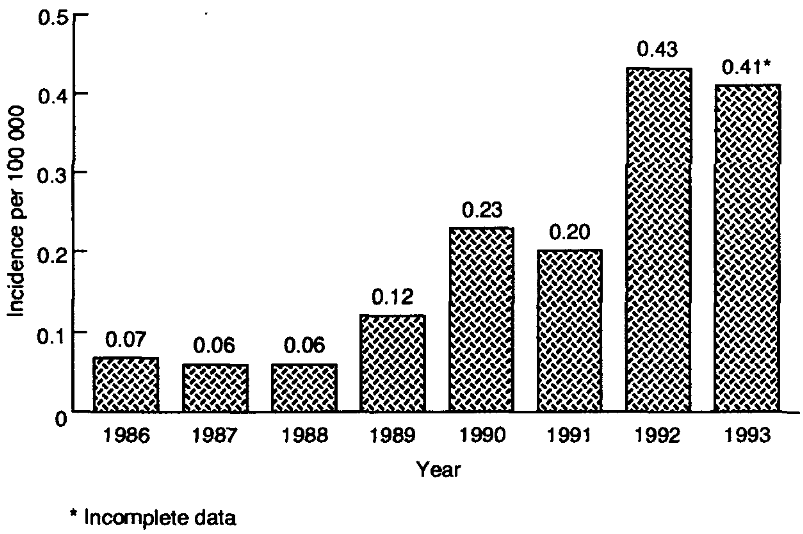

FIG. 3. Thyroid cancer in young people in Ukraine who were children 0–14 years old in 1986.

There has been a substantial increase in the incidence of thyroid cancer, especially in young children. Thyroid cancer in individuals who were children at the time of the accident will be the form of cancer most likely to be clearly associable with the Chernobyl accident. This is because of (1) the high thyroid doses compared with doses to other parts of the body; (2) the vulnerability of children to thyroid cancer; and (3) the low incidence otherwise of thyroid cancer, especially in children.

3. OTHER HEALTH CONCERNS

3.1. General health conditions following the accident

The health effects of the Chernobyl accident must be clearly dissociated from health effects arising from the thoroughgoing social, political and economic changes being brought about in the Soviet Union at the time. The period following the accident coincided with the period of 'perestroika', or restructuring, from 1987, which entailed a sharp downward trend in the economic indices such as in a war economy. The gross national product of Russia fell by more than 50%, industrial production by even more, and investment by perhaps 70%.

This economic collapse has had far reaching consequences for general health. If the poverty level is defined as that income below which the level of food consumption would be inadequate for maintaining normal body weight, then more than 46% of Russian children below the age of 15 and 37% of the general Russian population had incomes below the poverty level in 1992.

The economic collapse has also had a significant impact on the mortality rate (death rate) and morbidity (the incidence of disease) in the population. The crude death rate (Fig. 4) in Russia increased from 488 per 100 000 in 1990 to 741 per 100 000 in 1993, an increase of some 52%, and by 1993 the life expectancy at birth for Russian males had fallen to about 59 years, some six years less than it had been in 1987. Much of this fall in life expectancy for males was due to an increase in the number of deaths from 'non-natural' causes. A significant non-natural cause of death was the homicide rate, which more than doubled from 7.4 per 100 000 in 1986 to 15.2 per 100 000 in 1991. Another component was the sharp increase in the number of deaths as a result of traffic accidents.

There has been a general deterioration in the health of the population, as evidenced by increases in the incidence of diphtheria, measles, sexually transmitted diseases and tuberculosis. The health of pregnant women and the newly born has also

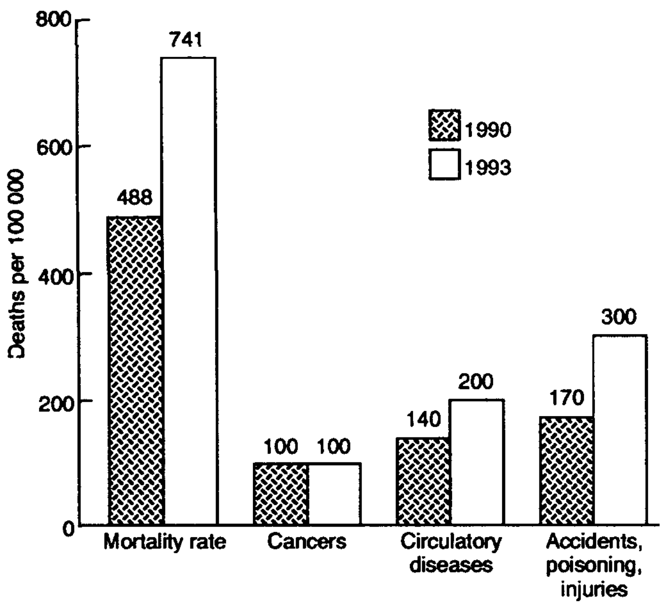

FIG. 4. Mortality for Russian males in 1993 in comparison with that in 1990. (Adapted from Ref. [18].)

declined. While this effect is not as striking as that for 'non-natural' causes, this trend in the general population should be borne in mind when assessing the incidence of disease and mortality associated with the Chernobyl accident, especially when considering crude death rates in middle aged men.

This deterioration in the health of the Russian population generally since 1987 is mirrored in the other successor states of the former Soviet Union. Examination of the statistics for the exposed population in neglect of the clear general increase in morbidity and mortality in the countries of the former Soviet Union has led to the misinterpretation that the trends seen were due to the accident. Many trends in health effects that are known not to be induced by radiation have mistakenly been attributed to the Chernobyl accident.

Many factors, such as economic hardship, are having a marked effect on the health of the population in general, including the various groups exposed following the Chernobyl accident.

3.2. Psychological effects

The distress and anxiety that followed the accident had many causes, including the social and economic disruption associated with evacuation and relocation, the restriction of land use, and shortages of 'clean' food. Studies have shown that symptoms of stress may be linked to a feeling of loss of control over one's circumstances. However, first and foremost as a cause was the uncertainty among the public about the long term health effects of radiation (Fig. 5): any minor health complaint was seen by many people as foreshadowing the onset of a radiation induced disease. Some young people have come almost to expect to suffer from illness and premature death.

These well documented circumstances had marked effects on the health and well-being of millions of people, in addition to the general trends in health in the former Soviet Union. Many factors have been cited: misinterpretation of international recommendations for radiation protection, leading to contradictory information and conflicting measures; misapprehension of the risk from the current levels of contamination; compensation schemes that reinforce false beliefs about supposed 'inevitable' health effects; a heritage of mistrust in central authorities; exploitation of the accident and its putative effects for vested interests; and inaccurate reporting.

Stress can be defined as the process by which adverse mental experiences have negative effects on bodily functions. The mechanism is physiological, mediated through the autonomic nervous system and the endocrinological system (see Background Paper 4).

The stress related health impact of any major accident will depend on many factors apart from the nature of the accident. A constant finding in studies of disasters is that, given sufficient stress, those affected will develop symptoms. The intensity

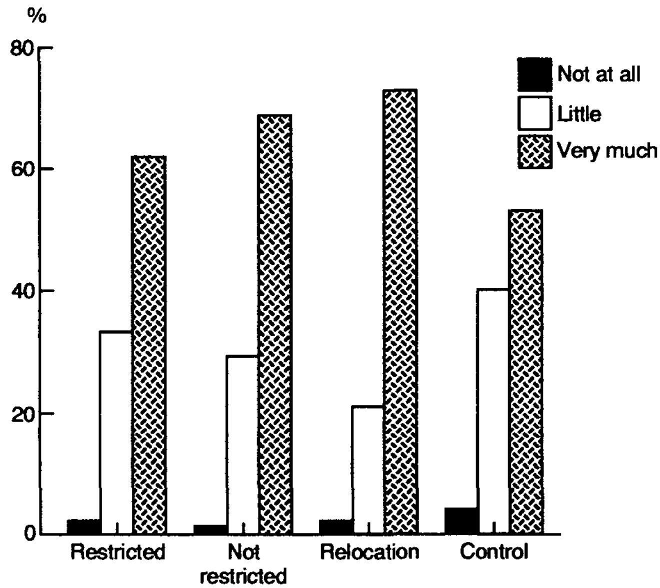

FIG. 5. Response by people living near Chernobyl to the question: "To what extent are you currently worried about health effects of radiation due to the Chernobyl accident for you and your family?"

or nature of the stress seems to be more important in determining the nature of the symptoms caused than the personality of the individual [19]. The post-traumatic syndrome, marked by depression, apathy, guilt and possibly alienation, has long been found in those who have survived disasters. Enormity of loss, contributing to a sense of futility and absence of hope, may play a significant role [20–22]. Such effects have also been seen in the population affected by the Chernobyl accident. For example, studies have shown that many people are fearful and uncertain about the future.

As Lee has suggested in Background Paper 4, perhaps the chronic stress disorder induced since the Chernobyl accident should be regarded as Chronic Environmental Stress Disorder (CESD) to distinguish it from the Post-Traumatic Stress Disorder (PTSD).

Table III shows selected non-radiological accidents and their consequences. The public reactions to the disasters in Seveso, Italy, in 1976 and Bhopal, India, in 1984 were similar to the reaction to the Chernobyl accident. The common features of the accidents appear to be the release of toxic material which had acute and long term effects. These features appear to reinforce the collective memory and

TABLE III. SELECTED NON-RADIOLOGICAL ACCIDENTS AND THEIR CONSEQUENCES

Year	Location	Accident	Consequences
1959	France, Malpasset	Dam rupture	421 deaths
1976	Italy, Seveso	Dioxin release	— No deaths — 800 evacuees — 100 ha contaminated
1984	India, Bhopal	Methyl isocyanate release	~3000 deaths ~170 000 people affected
1987	Philippines	Sinking of a ferry	4386 deaths
1989	Russian Federation	Pipeline explosion	Over 500 deaths
1992	Turkey	Methane explosion in a coal mine	Over 400 deaths

perception of the disaster. Even with the accident in Seveso, in which there were no fatalities, the public perception is one of a disaster. However, there are many examples of disasters that are not so remembered in the public consciousness, such as the sinking of a ferry in the Philippines in 1987 which caused over 4000 deaths, the pipeline explosion in the Russian Federation in 1989 which caused more than 500 deaths in two passing trains or the methane explosion in a coal mine in Turkey in 1992 with more than 400 deaths.

The psychological impact of the accident and of the continuing measures taken in response to it, although clearly important, are difficult to quantify. It is to be expected that people affected by the Chernobyl accident, as with any disaster, should develop symptoms such as anxiety that are associated with mental stress. These symptoms may be among the most important legacies of the accident.

4. THE SARCOPHAGUS AND THE VICINITY OF THE PLANT

Before the accident in April 1986, there were six reactor units at the Chernobyl site. Four were operational and Units 5 and 6 were under construction. Units 1 and 2 are early RBMK (light water cooled, graphite moderated) reactors in separate reactor blocks. Units 3 and 4 (Fig. 6) are RBMK reactors of a later design in which the units are in two blocks linked by a common central building (Block D) which has the single common chimney and accommodates some common services and the cooling water treatment plants.

After the accident at Unit 4 in 1986, the Ukrainian and Russian authorities constructed a 'containment' for the remains of the destroyed reactor. This structure (the sarcophagus or 'ukritiye') was erected with great urgency under extremely arduous conditions.

Units 1, 2 and 3 were closed down after the accident. They were restarted when the cleanup operations had been completed. Unit 2 was closed in 1992 following a fire which damaged the electrical generating system. There has been some indecision about the continued operation of Units 1 and 3.

The dose resulting from the dispersal of radioactive dust following a collapse of the sarcophagus has been estimated [23] to be less than 50 mSv/year at 2000 m from the plant for most conditions. Very high doses (>1 Gy) are only possible in the event of envelopment by dust at very close quarters (of the order of 100 m) to the sarcophagus.

There are considerable concerns about the risk associated with Unit 3, which adjoins the sarcophagus; present knowledge about the significance of that risk is inadequate. Since Unit 3, according to the Ukrainian authorities' statement of August 1995, is not likely to be closed before the year 2000, this issue is of

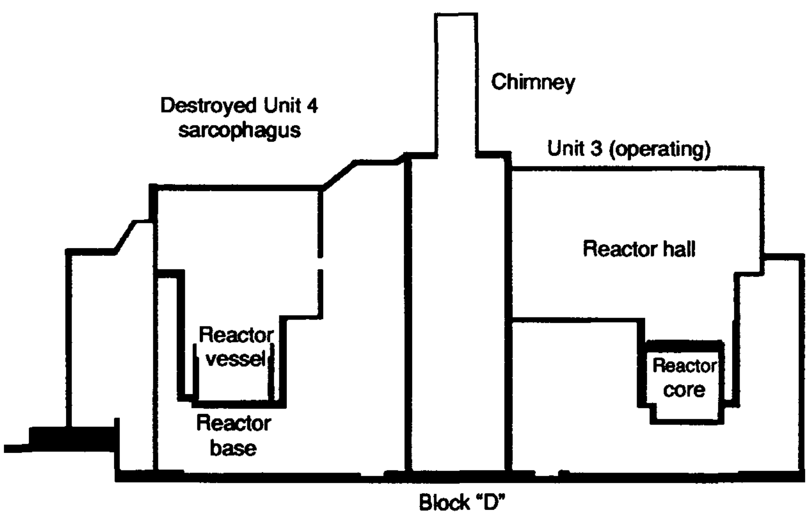

FIG. 6. Chernobyl Units 3 and 4: simplified elevation.

considerable importance. The potential for a collapse of the sarcophagus and the implications of such an event for nuclear safety at the operating Unit 3 need to be investigated.

Any significant doses from dust due to a collapse of the sarcophagus would be confined to the plant's immediate vicinity. However, a collapse of the sarcophagus could result in an accident at the operating Unit 3. Current knowledge of the likelihood and the potential consequences of such an event is inadequate and this issue requires study.

Several tonnes of irradiated fuel were dumped about the Chernobyl site. There are large amounts of material and equipment contaminated by fallout from the explosion on the ground to the west of Unit 4, inside the unfinished Units 5 and 6 and also in all the dumps. Also, there are some 200 tonnes of fuel within the sarcophagus. The material in the sarcophagus can be contained in the short to medium term and shielded from rainwater. Over the time-scale of the half-life of the radioactive material in dumps outside the sarcophagus, there will be an eventual escape of contaminated water, both from these dumps and also, if appropriate measures are not taken, from the fuel masses within the sarcophagus.

In the long term, the radioactive material buried at the Chernobyl site is likely to cause significant contamination of groundwater. The same applies for the fuel masses contained within the sarcophagus, if measures are not taken to improve the protection provided by the sarcophagus. These issues need further study in order to develop appropriate steps.

5. PREDICTION OF FUTURE HEALTH EFFECTS FOR 1996-2056

5.1. General

Future health effects are normally projected for 70 years from the accident (to the year 2056), as the standard human lifespan. Since the accident in 1986, several organizations and experts have sought to predict its likely future health effects to the year 2056. Reasoned predictions were in the range of 5000–10 000 excess fatal cancers in total for those living in the contaminated areas and for the liquidators, as discussed in this Background Paper. Larger or smaller estimates of excess cancers were made for different sizes and compositions of reference populations. However, the maximum excess of cancers attributable to the accident was consistently estimated to be in the range of 1–5% of the naturally occurring cancers in the contaminated areas. The total number of thyroid cancer was estimated at between a few hundred and a few thousand. The number of excess deaths due to leukaemia is estimated at about 1000.

If a radiation exposure leads to a cancer, there is typically a 10–30 year latency period between the exposure and the onset of the cancer. Careful studies over the next 10 to 20 years have the best chance of detecting an increase in the incidence of cancers that can clearly be statistically associated with the accident. However, epidemiological studies would be complicated by poor data on doses, difficulties in accurately identifying and tracking members of the exposed groups, difficulties in developing adequate control groups for comparative purposes, and the low number of excess cancers to be expected in comparison with the normal incidence.

5.2. Predicted health effects among the initial responders

The high doses received by the initial responders over the first few days after the accident, around 1 Gy or above, may increase the cancer rate in this group. The number of excess fatal cancers estimated is between none and a few tens, a reasonable estimate being around ten. These cancers are expected to occur up to about the year 2030. Therefore, it may be difficult to detect the excess cancers.

The majority of the more severely affected initial responders suffer from multiple ailments and are in need of up-to-date treatment. This group should be monitored over the next 20–30 years.

It is unlikely that any excess in cancers among the initial responders, if there be such an excess, would be detectable, because of the relatively small number of individuals in this group and the long period over which follow-up studies would be necessary.

5.3. Predicted health effects among liquidators and the public

The distribution of excess cancer deaths due to radiation exposure as a result of the accident per 100 000 liquidators has been calculated [5] for the 70 years following the accident (Fig. 7). The calculation is based on the accepted risk factors and the average reported dose for the liquidators who worked within the 30 km zone in the first year (165 mSv). Owing to the long latency period for most cancers, no significant rise in excess cancers would be expected until now. There is expected to be a steady rise for the next 15–20 years, after which the curve levels off because of the rapidly increasing normal death rate in the ageing population. The average age of the liquidators at exposure was about 35 years.

There are large uncertainties about the actual doses received by the liquidators. However, if the reported average doses are reasonably accurate, for the 200 000 liquidators working in 1986–1987, about 2000 excess fatal solid cancers are likely to occur, compared with around 40 000 'natural' solid cancers. This maximum figure represents a few per cent of the expected total number of cancer deaths in this group.

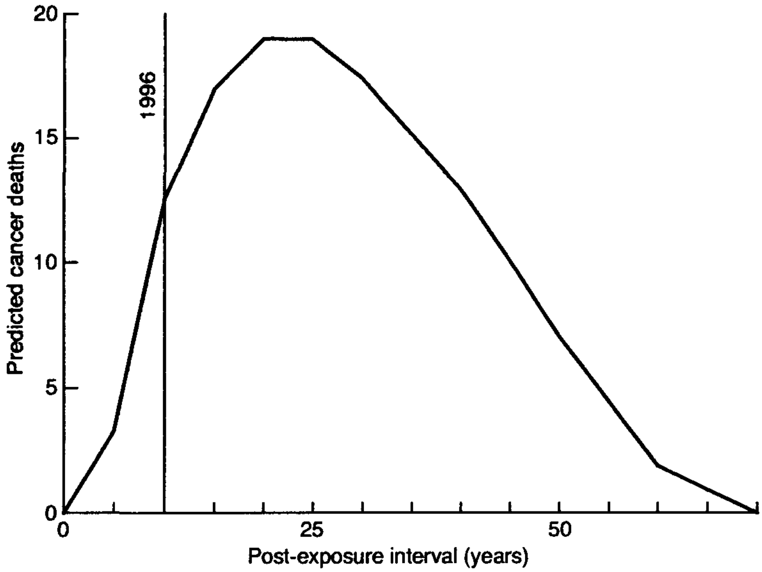

FIG. 7. Distribution of predicted excess annual fatal cancers among liquidators (employed in 1986, average dose 165 mSv) per 100 000 people, as a function of time since exposure. (Adapted from Ref. [5].)

While it is very unlikely that an epidemiological study of the whole population of liquidators would detect an increase in cancer incidence of only a few per cent, it is conceivable that a larger increase might be detectable in a smaller, higher dose group.

Among the 135 000 people evacuated in the first weeks after the accident, on the basis of the reported doses, the number of expected excess fatal cancers due to radiation exposure can be estimated to be fewer than 200, which would occur over the next 60 years. This is to be compared with about 22 000 'normal' cancers expected to occur among a similar population living in uncontaminated areas over the same period. The major concern for the future is thyroid cancer, which is discussed in Section 5.4.

Among the residents of all contaminated areas (over seven million people), on the basis of the reported doses, the number of expected excess fatal solid cancers due to radiation exposure can be estimated to be about 6000, which would occur over the next 60 years. This is to be compared with over 840 000 'normal' solid cancers expected to occur among a similar population living in uncontaminated areas over the same period.

Demin [24] has estimated health risks for the population of the Bryansk region in Russia. The study was not epidemiological but used a computer based model to predict the effects of doses among various age groups of the exposed population. It is interesting to note that, even in the most contaminated regions, the overwhelming predominance of the 'normal' incidence of cancer over the incidence of projected radiogenic cancers means that the latter are indiscernible from the former. This is illustrated in Fig. 8, in which the annual mortality from all cancers in 100 000 individuals is compared with those cancers which are predicted to occur owing to the doses resulting from the accident. Demin concludes: "It follows that the total radiological risk caused by the Chernobyl accident is rather low (especially for the adult population) in comparison with the health risk from all spontaneous cancers, even on territories with relatively high levels of radioactive contamination." This figure shows an increase of less than a few per cent in radiation induced cancers among the total cancers. This can be taken as a reasonable estimate.

On the basis of the current estimated doses for the liquidators and for the public, the projected excess total cancer incidence resulting from the accident would be indiscernible from the fluctuations in the statistical

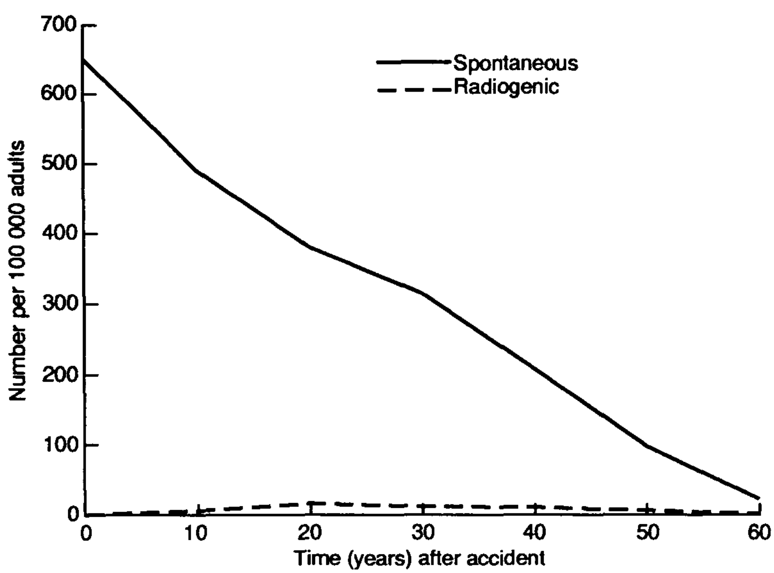

FIG. 8. Annual mortality from expected spontaneous cancers and predicted radiogenic cancers per 100 000 adults in the Bryansk region as a function of time since the accident. (Adapted from Ref. [24].)

incidence of normal cancers. Increases in leukaemia and thyroid cancer may be detectable. Nevertheless, because of the long delay between exposure and the appearance of solid cancers (the latency period), it is necessary to continue to monitor the exposed populations, especially those who received the highest doses.

One of the greatest concerns of the affected populations is the possibility of hereditary diseases appearing in the next generations. Today, there is no evidence of any excess of hereditary disease in children born since the accident. Hereditary disorders are frequent in man, so small changes in their incidence are difficult to detect. No such changes in incidence due to radiation have been demonstrated in human populations, even among the survivors of the atomic bombing of Hiroshima and Nagasaki in Japan in 1945. Experiments with plants and small animals have indicated that the frequency of radiation induced hereditary disorders will be less in the descendants of an exposed population than that of the radiation induced cancers in the exposed population. It is estimated that there will be an increase of less than 1% in hereditary disorders as a result of the Chernobyl accident. Therefore, it will most probably be impossible to detect any hereditary effects related to the Chernobyl accident in the future.

There is no evidence of any excess of hereditary diseases in the children born after the accident and no detectable excess is expected to arise.

5.4. Predicted incidence of thyroid cancer

If the increase in the incidence of thyroid cancer is caused by exposure due to the Chernobyl accident, as the group of young people who were 0–14 years old at the time of the accident in 1986 (the 0–14 year cohort) grow up, the incidence of thyroid cancer in children who were 0–14 years old will drop until it is close to the incidence prior to the accident. Therefore, a fall in the thyroid cancer rate in this group over the next years will indicate that the excess cancers were indeed due to the accident. As was pointed out in Background Paper 2, this cohort will have a risk of thyroid cancer which may be expressed at any time over the next 40 years, so that an increase in adult thyroid cancer also can be expected in this cohort as it ages. In addition, because of the apparently longer latency period between exposure and expression of thyroid cancer in adults, there would be expected to be a delayed increase in adult thyroid cancer, which would become evident over the next few years and which may continue for several decades.

Forecasting the future incidence of thyroid cancer is complicated by several uncertainties in the link between radiation exposure and the induction of cancer. The risk per unit dose to the thyroid seems to be influenced by the age at exposure, the form of radiation, and the ethnic origins and sex of those exposed. Children seem to be more susceptible than the population as a whole, probably by a factor of two or three. Furthermore, the reported dose estimates for the same areas have a range of uncertainty of a factor of three or more. There can be no consensus as yet on forecasts of the future incidence of thyroid cancer attributable to the Chernobyl accident.

As discussed in Background Paper 2, it is impossible to predict with certainty whether the current increased incidence of thyroid cancer will persist. If it does, a simple calculation can provide an estimate of the number of such cancers, on the assumption that one million people were exposed to an average dose of 500–1000 mGy to the thyroid. On the basis of this assumption, 4000–8000 excess cases of thyroid cancer would be projected in this population. This projection does not take into account the possible decrease in risk with time and, in addition, it is assumed that latency periods for thyroid cancer in children may be as long as those for adults. Thyroid cancer can be successfully treated and is not fatal in up to 90–95% of cases, so that the number of fatalities would be much lower. However, such a reduced mortality rate can only be achieved if the diagnosis is made in the early stage and appropriate treatment is given. If not, the mortality rate will be much higher. Further studies may provide a more accurate forecast of future increases in the incidence of thyroid cancer.

There will most probably be an increase in the incidence of thyroid cancer that will persist for several decades. While it is not possible to predict with certainty on the basis of current data, the estimated number of cases of thyroid cancer in those who were children in 1986 is in the range of a few thousand. The number of fatalities should be much lower than this if the cancer is diagnosed in the early stage and appropriate treatment is given. Members of this group should therefore continue to be closely monitored throughout their lives.

5.5. Future psychological effects

Past experience of accidents unrelated to radiation has shown that the psychological impact may persist for a long period. In fact, ten years after the Chernobyl accident, the evolution of symptoms has not ended. It can be expected that the importance of this effect will decrease with time. However, the continuing debate over radiation risks and countermeasures, combined with the fact that effects of the early exposures are now being seen, may prolong the time of occurrence of symptoms. The psychological impact cannot be completely dissociated from that of the breakup of the Soviet Union, and any forecast should therefore take into account the economic, political and sociological circumstances of the three countries. This interrelationship makes any precise predictions highly speculative.

One merit of the International Chernobyl Project [7] has been to increase the awareness of social problems and their influence on health and on the actions of the authorities since the accident. Operational aspects of radiological protection require an awareness of the social factors.

In view of the low risk associated with the present radiation levels in many of the contaminated areas, the benefits of future efforts to reduce doses to the public would be outweighed by the negative psychological and economic impacts. All potential impacts of future measures to be taken in response to the accident should be taken into account. In addition, measures to mitigate the psychological impact should be considered.

5.6. Tentative summary of the predictable effects

A summary of the predicted numbers of excess fatal cancers and cases of thyroid cancer attributable to the accident is provided in Tables IV and V. The numbers, which have been rounded, are derived from the estimates presented in this paper. They should be taken as rough indicators only. In no case are they intended to be precise estimates.

Consequently, projections of the cancer rate should be viewed primarily as indicators of trends and potential areas of concern warranting monitoring. For example, monitoring of exposed children for thyroid cancer or of the highly exposed liquidators for leukaemia is warranted.

6. PERTINENT QUESTIONS

The public perception of the present and future impact of the accident may have been exaggerated by the difficult socioeconomic circumstances in the Soviet Union at the time, by the countermeasures that the authorities have taken to minimize the accident's impact, and by the public's impression of the risks from the present levels of radioactive contamination.

In the management of the accident itself, certain decisions were taken which not only increased the costs of the response but also widened its impact. In 1989 a team from WHO reported to the Soviet Government that, had it been asked to propose a projected lifetime dose as a criterion for relocation, it would have chosen a figure two to three times higher than the 350 mSv adopted by the Soviet Government. However, decisions on measures of this type are not taken solely on the basis of lives saved or resources dedicated. For example, action may be taken to reassure the local population. In addition, many decisions were taken on the basis of data and perceptions that should now be re-examined in the light of the present understanding of the accident and its consequences.

Large amounts of money have been spent in attempts to alleviate the effects of the accident. Belarus is said to be spending 15–20% of its annual budget on activities related to the effects of the Chernobyl accident. Expenditure in other areas should be much more beneficial than this expenditure in terms of lives saved and living standards improved. For example, health care services are underfunded in all three Republics.

TABLE IV. PREDICTIONS OF THE TOTAL 'NORMAL' (BACKGROUND) AND EXCESS DEATHS FROM SOLID CANCERS AND LEUKAEMIA IN THE POPULATIONS EXPOSED AS A RESULT OF THE CHERNOBYL ACCIDENT (FROM BACKGROUND PAPER 3)

Population	Population size	Cancer type	Normal background number of cancer deaths	Predicted lifetime excess cancer deaths	
				Number	Per cent
Liquidators (1986–1987)	200 000	Solid cancers	41 500	2000	5
		Leukaemia	800	200	20
Evacuees from the 30 km zone	135 000	Solid cancers	21 500	150	0.1
		Leukaemia	500	10	2
Residents of the 'strict control zone' (>555 kBq/m^2)	270 000	Solid cancers	43 500	1500	3
		Leukaemia	1 000	100	9
Residents of other contaminated areas	6 800 000	Solid cancers	800 000	4600	0.6
		Leukaemia	24 000	370	1.5

TABLE V. ESTIMATE OF THE NUMBER OF CASES OF THYROID CANCER (ROUNDED VALUES)[a] LIKELY TO OCCUR IN THE MOST AFFECTED POPULATIONS AS A RESULT OF THE CHERNOBYL ACCIDENT

Group at risk	Number of individuals	Expected number of natural cancers	Number of attributable cancers[b]
Children 0–14 years old in 1986	1 000 000	10–40	4000–8000 (200–800 fatal)

[a] The total number of cases of thyroid cancer is expected to be at least ten times higher than the number of fatal cancers owing to the relatively good prognosis for thyroid cancer.
[b] This is about one hundred times normal.

This leads to the question: *Were the dose levels at which protective actions were undertaken (intervention levels) set too low?*

The social and psychological effects of the accident may well have caused the most widespread indirect health effects. The problem arises in disaster management that some decisions may enhance the economic and psychological effects of the accident. This prompts the further questions:

Is compensation an effective way to deal with exposure?
What is compensation offered for?
— *Is it for the increased risk of cancer?*
— *Is it for the disruptive effect of the accident on social activities?*
— *Is it for the loss of property or employment?*

According to the general practices in other developed societies, compensation should only be offered for alleviation of a specific detriment, such as the development of a disease or loss of property or employment. There should be no compensation offered for an increased *risk* of cancer, before it has actually developed, only once it has developed.

Is close and continued monitoring of any groups of the exposed population warranted?

There are several groups that may benefit from increased medical monitoring and treatment in the future. Those individuals who were children at the time of exposure should be monitored for thyroid cancer. The initial responders who received very high doses should be monitored for a range of possible health effects. Finally, the most highly exposed liquidators may benefit from monitoring for leukaemia over the next few years.

The question in conclusion is:

What policies can now be developed to take into account both the real radiological risk and the economic, social and psychological impacts, and to yield the greatest benefits in human terms?

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DISCUSSION ON BACKGROUND PAPER 8

V.F. MAZHAROV (Russian Federation): In studies of the health of the rural population living near a nuclear facility in the Krasnoyarsk region (Siberia), we have noted effects characteristic of damage due to radiation. Unfortunately, no comprehensive assessment has yet been made of the health-related radiation situation in this region, but pilot studies by Prof. P.V. Ramzaev point to disproportionately lower levels of radiation contamination. I should be interested in hearing, in this connection, opinions about the possible impact of low doses. According to some authors, with low doses radiation damage occurs at levels 5000 times lower than those officially recognized. Could this be relevant for the long-term studies to be carried out in the areas affected by the Chernobyl accident?

J.-C. NENOT (France, Rapporteur): This is a difficult issue, and we did not go very deeply into it in our Background Paper. If you perform a simple multiplication, taking a huge number of people and very low doses, you obtain a certain number of cancers, but I doubt whether that number has any real meaning. In our Background Paper, therefore, we focused on the groups which had received the highest doses.

I would not like to give even a very tentative figure for the number of cancers resulting from low doses.

K.P. DUNCAN (United Kingdom, Chairperson): This question was raised during an earlier topical session [Topical Session 3], at which time Prof. R.H. Clarke talked about the ''disaggregation'' of collective doses. The question, about which there is much uncertainty, deserves a scientific meeting of its own.

G.G. NASTRI (European Commission): It might be interesting to study the health effects of large-scale population relocation by comparing what has happened as a result of the Chernobyl accident (where radioactivity has been involved) and what has happened in, say, the former Yugoslavia and Chechnya (where radioactivity has not been involved).

D.C. GARNER (United States of America): In the Background Paper there is a reference (in Section 2.2.2) to cardiovascular conditions as a major cause of death among the liquidators and (in Section 3.1) to 'non-natural' causes of the fall in the life expectancy of males — for example, homicides. I think it might be interesting to look into whether deaths due to such non-cancer-related causes falsely mask a potential increase in mortality due to radiation-induced cancer.

E.I. BOMKO (Ukraine): I think the following two tables (Tables I and II) may be of interest. The first one relates to a cohort of boys who were seven years old in 1993.

TABLE I. MEAN COHORT SERUM FOR CHILDREN WHO WERE EVACUATED FROM PRIPYAT AND LIVING IN KIEV (boys 7 years old in 1993, born in 1986)

Exponents	Quantitative level
Height	121.0 ± 1.1, σ = 6.02
Weight	22.3 ± 0.6, σ = 3.46
TSH	1.9 ± 0.03 μIU/mL
FT4	13.6 ± 0.17 p mol/L (delfic)
Haemoglobin	128 ± 0.4 g/L
Red blood cells	4.72 ± 0.02 × 10^{12}/L
White blood cells	5.7 ± 0.05 × 10^{9}/L
Platelets	254 ± 2.1 g/L
Reticulocytes	0.5 ± 0.003%

TABLE II. CASES OF THYROID CANCER AMONG EVACUATED CHILDREN LIVING IN KIEV FOR THE PERIOD 1986–1995

Age at the moment of the accident	Number of cases	Number of person-years	Total effective equivalent dose in1986 (mSv)	Mean-age dose on the thyroid (cGy)	Age estimation per 100 000 person-years
0–4 (1982–1986)	3	29 007	20	200–280	10.3
5–9 (1977–1981)	2	24 767			8.1
10–14 (1972–1976)	0	4 447			0
	5	58 221			

M.R. QUASTEL (Israel): The health effect predictions made in the Background Paper are, of course, only educated guesses based on what we think happened in the past. What we need now are well-planned prospective epidemiological studies on a co-operative multinational basis, covering the three affected Republics and the Chernobyl "diaspora", with biological and statistical techniques which are agreed upon and intercomparable to be used in the comparison of populations exposed to lower and higher radiation levels.

V.K. IVANOV (Russian Federation): In order to predict numbers of cancers among the liquidators, it is necessary to know their age distribution and the doses received by them. As regards their age distribution, it should be borne in mind that many of the 1986–1987 liquidators were young soldiers who are still only about 30 years of age. As regards the doses received by the liquidators, the present data on the incidence of thyroid cancer and leukaemia suggest that the figure of 165 mSv for the mean dose received should be reduced by a factor of 1.5–2.

Thus, the figure of 1000 for excess cancers per 100 000 liquidators may be wrong by a factor of 2–3.

E.D. WILLIAMS (European Commission): I believe it is important that a conference like this not give the impression that the participants are interested only in the results of what they see as a large-scale experiment in which the affected populations in the three Republics are guinea-pigs. Accordingly, I believe that those in the three Republics who were exposed as children to high radiation levels as a result of the Chernobyl accident should be screened for thyroid cancer, not only because of the direct benefits which this would bring but also because this would reassure the affected populations that the scientific community is concerned to help and is translating its concern into action.

While it is easy to recommend screening for thyroid cancer, the evidence suggests that it is likely to be cost-effective to restrict the screening to those children who were no more than a few years old at the time of exposure. Whatever age groups undergo screening, however, the scientists' desire for more information regarding the relationship between age at exposure and the risk of developing thyroid cancer should not be allowed to delay humanitarian action.

In my view, the various agencies interested in the thyroid cancer problem should co-operate with the three Republics in organizing a programme of targeted screening.

V.I. GLAZKO (Ukraine): At the Institute of Agroecology and Biotechnology in Kiev, we have studied the genetic structure of cows which survived the Chernobyl accident. We did not find any mutations, but there were changes in genetic structure. The progeny of cows raised for their milk had become more similar in genetic structure and phenotype to cows raised for their meat, the latter being more primitive

— more adaptive. This indicates pre-zygotic selection and a breakdown of the equiprobable transfer of gametes. Also, not all of the cows produced progeny.

We have obtained similar results with inbred mice in studies in which we are now working with the tenth generation.

In this connection, I would draw attention to poster papers CN-63/327 and 328 and call for the establishment of a special programme for the study of the genetic consequences of the Chernobyl accident.

E.V. IVANOV (Russian Federation): When considering the effects of radiation exposure and making predictions, it is necessary to bear in mind the protective measures being taken. Anticarcinogenic protection promises to be the best way of limiting the consequences of radiation exposure due to the Chernobyl accident. Very effective food additives for reducing the incidence of tumours in high-risk groups already exist; they can completely eliminate the effects of radiation exposure.

J. JOVANOVICH (Canada): In connection with Table III of the Background Paper, on "selected non-radiological accidents and their consequences", I should like to raise the question of air pollution. As far as I am aware, the tolerance limits and risk factors accepted in the case of air pollution are far higher (sometimes by as much as two orders of magnitude) than those accepted in the case of radioactive contamination. I should be interested in hearing the views of other participants on this question.

J.-C. NENOT (France, Rapporteur): Regrettably, radiological protection tends to be considered in isolation from protection against non-radiological hazards. I should like to see similar levels of protection provided against all hazards, such as radioactive contamination and air pollution.

K.P. DUNCAN (United Kingdom, Chairperson): People working in fields like occupational medicine are well aware of such differences in levels of protection, which pose a big problem.

C. ZUUR (Netherlands): As regards the comparative risks associated with air pollution and radioactive contamination, I would mention that in the Netherlands we have a system — which has been working well for the past ten years — whereby the permitted risk due to all radiation exposures (internal and external) is the same as that due to all chemical materials from all sources and the same as the risks associated with potential exposures (to chemicals and to radiation) due to accidents. Details can be obtained from our Ministry for the Environment.

A.R.J. AL-ASFOUR (Kuwait): As there is a positive correlation between cancer incidence and life expectancy, a decline in life expectancy in regions affected by the Chernobyl accident is likely to exert a downward pressure on the cancer incidence figures.

Another point perhaps worth bearing in mind when one is looking to the future is that the factors affecting the mood and behaviour of individuals are not the same as the factors affecting those of society at large.

K. MÜCK (Austria): In the first paragraph in Section 2.1 of the Background Paper, it is stated that the remaining 30–50% of the dose due to living in the contaminated regions of the three Republics will be received over the next 60 years. I think that 30–50% is an overestimate.

Observations of the decline in exposure levels in Austria after the Chernobyl accident indicate an effective half-life of two years, rather than the 4–5 years noted after the nuclear weapons tests (effective half-lives of around two years were estimated also in Czechoslovakia, Germany and Russia). With an effective half-life of two years, the additional exposure over the next six decades will account for 20% at most of the dose due to living in the contaminated regions.

Yu.S. RYABUKHIN (Russian Federation): In Table II of the Background Paper, the number of childhood thyroid cancers in the Bryansk and Kaluga regions during the period up to 1995 is given as 23. I should like to point out that the number reported by Prof. Tsyb for thyroid cancers among children in the affected areas of Russia is 104.

V.M. PONOMARENKO (Ukraine, Vice-Chairperson): I should like to comment on a number of points raised in this conference and at other meetings connected with the Chernobyl accident.

A certain degree of distrust has been expressed with regard to the data on the accident's consequences presented by the three Republics. I would point out in this connection that for several years the competent authorities in the three Republics have been co-operating closely with WHO, the European Commission, the Radiation Effects Research Foundation in Hiroshima and various other bodies interested in the correctness and objectivity of our data. As far as Ukraine is concerned, the national register of liquidators could be improved, but I think it is reasonably reliable.

In this connection, I would mention that before the death of an individual who underwent radiation exposure due to the Chernobyl accident is attributed to radiation exposure, the case is very carefully examined by an expert commission. Of the 158 165 deaths to date of individuals — liquidators, children and others — who were exposed in Ukraine, 3119 have been attributed to radiation exposure.

The radiation dose attributable to the accident has been described as fairly low. In Ukraine, we have assessed the total external dose being received and have arrived at a figure of about 5.3 mSv/year, of which about 1.5 mSv/year are due to X ray examinations.

The question has arisen as to whether countermeasures are necessary in situations where contamination levels are low. The international scientific community will, I hope, agree with us about the importance of bearing in mind social and psychological factors when deciding on countermeasures. In this connection, I would mention a survey carried out by us in which the Chernobyl accident was cited by people living in rural areas as probably being the third most frequent cause of death in Ukraine, while people living in urban areas cited the accident even as the number-one cause.

I cannot agree with those who are playing down the need for countermeasures. I believe that there will be a continuing need for countermeasures in the light of — inter alia — further dose reconstruction work, further radiological monitoring and further population health monitoring. Also, one must not forget the problem of the radioactive waste.

CONCLUDING SESSION
OF THE TECHNICAL SYMPOSIUM

Chairperson

A. MERKEL
Germany

CONCLUSIONS AND RECOMMENDATIONS OF THE TECHNICAL SYMPOSIUM

Presented by

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Topical Session 1: Clinically observed effects

The symptoms caused by high levels of exposure to radiation are summarized under the term ''acute radiation sickness'', abbreviated to ARS. Initially, the most frequent symptoms of ARS are nausea, vomiting and diarrhoea, followed, at a later stage, by internal bleeding and infections with high fever, which are often caused by micro-organisms that are normally harmless. If not treated, ARS leads to death.

Clinically, effects were observed by examining a group of persons who complained of symptoms and were acutely exposed to medium or high doses of radiation during the accident. This group includes reactor staff as well as all other persons that were present on the site, especially the members of the fire brigade.

From a total of 237 people, 134 were diagnosed as having symptoms of ARS. Clinical treatment was found to be necessary in 134 cases, of which 37 were life threatening. Out of those 37 persons, 28 died within days or weeks after the accident, in spite of intensive treatment. Two more persons died at the site of the accident following the explosion, and one person died of cardiac infarction. Thus, a total of 31 people died during the first three months.

Before Chernobyl, bone marrow transplantation was considered to be the method of choice for treatment for radiation induced bone marrow damage. After Chernobyl, this therapy can be said to have failed, primarily as a result of inhomogeneous exposure and the other injuries caused by the accident, in particular skin burns. Inhomogeneous exposure leads to insufficient immunosuppression of the recipient, causing the immune system to reject the donated bone marrow. The reverse process could be observed as well: donated bone marrow was not sufficiently cleaned of the immunocells of the donor, so that these cells attacked the recipient's tissue. The process was further complicated by accident related injuries, in particular by often large scale skin burns, as well as by beta radiation.

Today, the administration of haemopoietic growth factors, which stimulate the recovery of haematogenic bone marrow parent cells, is considered to be a much better therapy, although very little experience has been gathered in this field. Other methods must only be considered after extremely high exposure, when a sufficient number of cells is no longer available. Progress in haemopoietic stem cell biology, with respect to both the use of other than marrow stem cells and their isolation, have made stem cell infusion considerably less risky than transplantation of bone marrow.

A rapid diagnosis of the extent of radiation injury is of extraordinary importance for determining the best method of therapy. New molecular parameters nowadays allow a better assessment of gastrointestinal injuries than was possible with the traditional indicators of vomiting and diarrhoea. Progress in understanding the molecular processes of acute inflammation reactions after irradiation of the skin and the introduction of new image generation processes both make the assessment and quantification of radiation injury to the skin easier than was the case in 1986. Furthermore, methods of diagnosis regarding the reduction of stem cells were improved considerably as well.

A substantial percentage of ARS survivors still suffer from what are often multiple diseases which require further treatment. This also applies to patients' mental and psychological condition. It can be anticipated that the frequency of multiple diseases will further increase and that the risk to develop tumours is also increased. Therefore, further medical care and follow-up must be ensured for the next two or three decades.

In conclusion, it can be said that scientific progress, in both diagnostics and treatment, is today offering victims of radiation a much higher chance to survive and a higher quality of life than was the case for the victims of the Chernobyl accident, although it should be emphasized that the persons injured in 1986 were given the best treatment available at the time.

Topical Session 2: Thyroid effects

A major increase in the number of cases of thyroid carcinomas has been recorded since 1990 in the areas exposed to high doses of fallout from Chernobyl. This increase has been almost exclusively among children, it is greatest in southern Belarus and northern Ukraine, and the diagnoses in these areas have been confirmed. A smaller increase has also been reported from the contaminated areas of the Russian Federation.

The great majority of these cases are papillary carcinoma, about half showed metastases spread into the tissues around the thyroid gland and spread to lymph glands in the neck, and a small number have died with lung metastases. This aggressiveness of the thyroid cancer is one of the reasons why we can conclude that screening has not much influenced the size of the increase that has occurred.

The relationship of this increase in childhood thyroid cancer to exposure to fallout from Chernobyl is shown by the geographical distribution of the cases, which broadly corresponds to the distribution of fallout in Ukraine and Belarus. The temporal distribution of the cases shows also that the incidence in children born more than 6 months after the accident is falling dramatically. The thyroid starts to concentrate iodine at about 3 months of intra-uterine life.

Exposure specifically to isotopes of iodine is considered to be the most likely cause of the increase in thyroid cancer. The significant increase in cancer following Chernobyl is confined to the thyroid, since radioiodine is the component of fallout which gives a very much higher dose to the thyroid than to other tissues, and large amounts of radioactive isotopes of iodine were present in the Chernobyl fallout.

Very young children from the exposed areas showed very much greater increase than older children in the observed incidence of thyroid cancer as compared to the expected incidence. It is known that after exposure to X rays young children developed more thyroid cancers than older children and it is also known that very young children showed a higher uptake of radioactive iodine than older children. The combination of these two factors can explain the observed high increase of the thyroid carcinogenic effect of exposure of very young children to fallout from Chernobyl. The drop in sensitivity with increasing age is also relevant for the safety of the use of radioactive iodine in the treatment of hyperthyroidism in adults.

The incidence of thyroid cancer in the future is difficult to predict accurately. It is likely that those exposed at very young ages form a cohort that will carry an increased risk of thyroid cancer, and that there will be a large increase in thyroid cancer in the future. Therefore, continued follow-up of this cohort is urgently required.

Fortunately, most cases of thyroid cancer can be cured by effective clinical treatment. According to previous experience, thyroid cancer normally has a lethality rate of some 10%. It is to be hoped that the chance of recovery will be similar for this more aggressive form of cancer.

As regards the area of prophylactic treatment, the importance of a timely intake of stable iodine has become clear. The optimum time for administration is just before the absorption of radioactive iodine, i.e. before the plume has passed. A satisfactory blocking reaction is still possible until a few hours after the uptake of radioactive iodine. An administration of iodine more than one day after the uptake of radioactive iodine is counterproductive, because it would prolong the biological half-time in the thyroid, and thus increase the dose.

Topical Session 3: Long term health effects

In principle, an increase in the number of cases of cancer, both solid tumours and leukaemia, is to be expected as a long term consequence of irradiation. To make a scientific statement on a significant increase, comparisons of risk must be made between groups with different levels of exposure. For this, an effort must be made, where possible, to reconstruct or estimate doses, on an individual basis for the subjects under study.

After the Chernobyl accident, an inventory was established to ensure epidemiological monitoring of four different groups of population. These are the liquidators, the evacuees, the inhabitants of the highly contaminated areas ("strict control zones") and the offspring of these groups. These are being "actively" monitored, i.e. they have to undergo medical check-up once a year. In addition, data are being recorded about their places of residence, nutrition, stays in contaminated areas, etc. In contrast, the general population of the affected countries is only "passively" monitored, i.e. with the help of general demographic data with regard to cause of death, illnesses, etc.

Up to 800 000 people were used as so-called "liquidators". Among these, approximately 200 000 liquidators worked in 1986–1987 when doses were highest. According to current estimates, the average dose among these was approximately 100 mSv, although the time during which it was absorbed ranged from minutes to months, even years. The liquidators included persons who were involved in eliminating the consequences of the reactor accident, building the sarcophagus, decontaminating houses and streets and burying contaminated materials; liquidators further comprise physicians, teachers, cooks, etc. who worked in the contaminated territories. Dosimetric data were recorded for part of this group. Often, however, these data are only rough estimates. Unfortunately, for many liquidators, there are no such data at all.

The group of evacuees consists of the former residents of the 30 km radius zone. Some 135 000 people were evacuated, including the 49 000 inhabitants of Pripyat. The dose values of the evacuated persons were reconstructed. The average doses ranged between 10 and 20 mSv; however, it should be noted that individual doses vary greatly. Up to 400 mSv has been calculated as a maximum value.

Today, approximately 4 million people are permanently living in areas with ^{137}Cs contamination levels of more than 37 kBq/m^2. The total area showing this level of activity is approximately 131 000 km^2. In 1986, some 270 000 people were living in the strict control zones, i.e. in areas where ^{137}Cs concentrations still exceed 600 kBq/m^2.

The health effects recorded to date can be summarized as follows. Apart from the dramatic increase in the number of cases of thyroid cancer in young people, no other types of cancer have so far been found to have increased in a significant and consistent way in relation to radiation exposure. In any case, an increase in the incidence of solid tumours has not been expected to occur yet, owing to their latency period. In particular, no consistent increase in the incidence of leukaemia has been observed. If the atomic bomb survivor experience is applicable, a four-fold increase compared to natural incidence would have been expected for the group of liquidators within the first ten years. Concerning other cancers, no major increase is predicted in the exposed populations on the basis of data from epidemiological studies. Our present knowledge, however, refers primarily to high doses over a short period, not to the low doses over a long period, which is found in contaminated areas. Our knowledge of the effects of different radionuclides and types of radiation is not complete. Furthermore, we do not know all the modifying factors and the relevant transfer and prognostic models. Therefore, further systematic and passive monitoring of the state of health (in particular cancer) must be done through the use of population based registries. In addition, careful focus studies of specific diseases and populations, e.g. leukaemia among liquidators, should be carried out in order to reduce the uncertainties in radiation risk estimates and consolidate the basis for radiation protection.

Nevertheless, increases in the frequencies of a number of diseases among liquidators and among populations in contaminated territories have been reported. This is to be considered as an indication of possible effects. But in the absence of systematically collected population data these reports are presently difficult to interpret, as they may reflect differences in health monitoring between exposed and non-exposed populations.

Topical Session 4: Other health related effects

Psychological consequences such as stress, for instance, are a major after-effect of the disaster. The group of people affected by stress goes far beyond those who live in contaminated areas. One of the reasons is certainly that the population is well aware of the highly erratic deposition of radioactivity. The particularly inefficient policy of information during the first couple of months still has an effect, even years later. In addition, the accident, which had a destructive impact upon the social environment, took place at a time when the centralized political and economic system broke down.

At this time, it should be clearly pointed out once again that stress can be proved objectively by a number of physiological indicators. It has nothing to do with "imagination". There is a causal link between a number of illnesses and stress — even the weakening of the immune system can no longer be excluded.

For those who were "on the spot", the psychological consequences of the Chernobyl disaster can be encapsulated in the term "post-traumatic stress disorder". This is a syndrome, caused by specific disasters, such as an earthquake or particular war situations, which go far beyond normal experience and lead to extreme emotional anxiety.

This description does, however, not apply to the far greater number of people with similar symptoms. Other factors play a role in this context: people were resettled; their food was restricted without a reason being perceptible; limit values for contamination were constantly changed; concerns about future health risks increased steadily and the erratic handling of countermeasures caused increased confusion. This is what leads to a feeling of helplessness. The conference suggested that these symptoms be summarized under the term "chronic environmental stress disorder".

There are basically three ways of reducing stress and thus reducing the psychological health impact arising from stress.

The best method, i.e. to remove the stressor, is not easily applicable in this case: the catastrophe has already taken place and cannot be undone, although huge efforts have been made to reduce contamination of the environment.

What remains, is to convey to those concerned that they have a certain control over the stressor and can thus change their perception of it. This control over the stressor, however, is only possible if people can, to a certain degree, decide by themselves whether they want to be resettled or not, whether food will be controlled, or at least monitored and when a social dialogue on these topics is to be held. As with the change in perception, an open policy of information is of vital importance here as well.

The solutions to the problem are more closely related to communications than to medicine.

Topical Session 5: Consequences for the environment

The discussions in Topical Session 5 did not focus only on direct effects on the environment "per se", but also on research relating to the indirect consequences for humans. In other words: what impact do contamination or the countermeasures taken have on areas such as agriculture, forestry, hunting and fisheries? The impact on flora and fauna in the region directly affected was seen in the short time for conifer trees and small animals as examples. Longer term impacts remain to be studied.

Initially, it was ^{131}I which had a major impact on humans, as a result of inhalation and from the grass-cowmilk pathway. In subsequent years, external gamma exposure and ingestion of ^{137}Cs in foodstuffs have been the main contributors to the dose.

Meadows, grasslands, agricultural land and woods, summarized under the collective term "semi-natural environments", are particularly important for human beings in the CIS. Ten years after the disaster in these environments, 70–90% of the originally deposited ^{137}Cs is still to be found in the topsoil. This causes a considerably higher concentration of ^{137}Cs in venison, mushrooms and berries in the forest. It should be mentioned that forest products have traditionally constituted a major percentage of the diet in the areas affected by contamination and therefore can be a major contribution to human dose. The concentration of activity is also above the accepted limit values in other animals grazing in these areas, such as sheep, goats or reindeer.

Agricultural products are among the main contributors to the dose. To stay below the limits for the radiation dose, countermeasures were taken in many regions, which in turn had consequences: land and products now need to be monitored; there have been changes in cultivation and feeding; fertilizers were used; and special manufacturing methods have been developed to keep the concentration of activity in foodstuffs low.

The decontamination methods which were regarded as useful have been replaced by efficient new decontamination methods, especially in residential areas. The amount of waste generated during this process, however, constitutes a secondary problem for which a satisfactory solution has not yet been found.

Topical Session 6: Social, economic, institutional and political impact

The economic impact, initially on the Soviet economy and subsequently on the economies of the Newly Independent States, was and is huge. Restrictions in forestry and silviculture were what mostly affected the areas concerned — hundreds of thousands of hectares could no longer be used in the traditional way. Resettlement led to a breakdown of the social network. The overall health situation deteriorated. Insufficient energy supplies, in particular electricity, had an additional negative impact. This resulted in a sharp drop in the standard of living of the overall population.

The social, institutional and political functions have been questioned by the accident and need to be re-established, taking into account the new situation. The key factor here is the direct involvement of all levels in society.

The application of the "classical principle of radiological protection", i.e. optimization of protection, in the decision making process is one of the driving forces during the initial phases of accident management.

This is at the same time the phase during which a hierarchical structure is useful. In the aftermath, however, a decentralized approach and a policy of information, transparency, acceptance and motivation is required to take social and psychological factors into account.

Normally, people are ready to accept risks in everyday life. They believe experts in such situations and do not question the legitimacy of the authorities.

In the aftermath of a disaster, this attitude is questioned. Social confidence dwindles. People are confronted with contamination and countermeasures in their everyday life. The loss of confidence in experts and authorities leads to confusion and to a feeling of complete helplessness in a complex situation. The stress and anxiety resulting from this lead to an ever increasing demand for better protection measures and additional compensation.

Decentralized approaches with a direct involvement of the people concerned could be a way out of this situation. The ways of post-accident management need to be reconsidered. The objective cannot be to return to the pre-disaster situation, this is no longer possible. It is then important to handle the situation in a positive manner. For those concerned, the path towards "normality" leads to voluntary involvement in building a new social structure. To achieve this, it is necessary for the population to be acquainted with the facts as early as possible. There must be an open discussion on dose values, and on the expected impact upon both health and the economy. Limits need to be defined; for instance, no countermeasures need to be taken if the annual dose is below 1 mSv, resettlement is required if the annual dose is, for instance, above 50 mSv, and for any values in between, optimization measures have to be found and implemented. Such decisions must be transparent, acceptable and be supported by those concerned. In addition to this, the system of compensation could be replaced by a system of gratification encouraging those having achieved a real improvement of the situation. At the same time, everyone living in an area in which the annual dose is between, for example, 5 and 50 mSv, should have the option of being resettled on a voluntary basis. By doing this, the stressor "resettlement" can be controlled.

In summary, a result of the discussion was that information, transparency and voluntary commitments of autonomous and directly involved people could be a new approach enabling people in affected areas to set up a new positive and future oriented social system for themselves.

Topical Session 7 : Nuclear safety remedial measures

The International Forum "One Decade after Chernobyl: Nuclear Safety Aspects" came to conclusions on a range of important issues regarding the causes of the accident, the safety of RBMK plants and the particular problems at Chernobyl.

The investigations performed within the programmes of the European Commission, the IAEA, and the EBRD contributed essentially to achieving these positions. It must be recognized, however, that those analyses could not reach the depth and the level of detail of safety analyses required within a licensing process. This is mainly due to the fact that there were no long term efforts in discussion, independent analysis and research on RBMK technology, and very little background knowledge is available on RBMK safety in western organizations. These limitations are of particular relevance, as RBMK technology fundamentally differs from the reactor technology used in Western countries.

Nuclear safety

In accordance with a dynamic approach to safety, all nuclear power plants that do not meet an internationally acceptable level of safety need appropriate upgrading or should be shut down. In 1991, the IAEA conference "The Safety of Nuclear Power: Strategy for the Future" formulated a consensus that "safety standards of older operating plants should be reasonably compliant with current safety objectives". Active commitment to this objective remains of prime importance for ensuring an acceptable level of safety for nuclear installations and for increasing public confidence in nuclear energy.

The main causes of the Chernobyl accident were the coincidence of severe deficiencies in the reactor physical design, the design of the shutdown system and the violation of procedures. The lack of "safety culture" in the responsible organizations of the Soviet Union led to the inability to remedy such design weaknesses, even though they had been known before the accident.

A significant number of nuclear safety remedial measures was undertaken during the past decade at the existing RBMK plants, essentially removing the design deficiencies contributing to the accident. As a result, a repetition of the same accident scenario seems practically no longer possible today.

For all RBMK reactors there exist plans for further safety upgrading regarding further RBMK design deficiencies that are not directly related to the Chernobyl accident. Accelerated implementation of what is agreed necessary has been identified as a top priority for the national nuclear programmes as well as for international co-operation:

- necessary safety improvements must be carried out independently from consideration of early decommissioning of the plants; when safety risks cannot be eliminated, the power plants in question have to be decommissioned as soon as possible;
- more resources must be made available for the safety of the RBMK plants currently operated;
- the status and the autonomy of national regulatory authorities must be strengthened.

Similar backfits as for other RBMK units were also performed at the Chernobyl NPP. However, safety concerns with these units are not only related to the remaining generic design deficiencies but also to the quality of equipment.

The group took note of the Ukrainian decision to close the remaining units of the Chernobyl NPP. However, this decision should not result in neglecting safety needs and backfits during the remaining time of operation.

Sarcophagus

The sarcophagus around the destroyed reactor has met its protective objectives for ten years now. In the long term, however, its stability and the quality of its confinement are questionable. A collapse could lead to a release of radioactive dust with significant exposure of the personnel employed at the site. But even in the worst case, widespread effects (outside the 30 km zone) are not expected.

The safety of the remaining units and the stability of the sarcophagus are not the only important problems to be solved at the Chernobyl site. Further concerns relate to the contamination, in particular to the radioactive material buried at the site. All these issues are closely interrelated and an integrated concept is therefore required to solve them. The proposed construction of a second shelter should be part of that approach.

A cost effective procedure requires suitable steps according to the progress of investigations and the financial conditions. The first step should be the stabilization of the existing sarcophagus. This step would significantly reduce the risk of a collapse of the shelter and thus provide the time required for careful planning of further measures (e.g. a second shelter).

Topical Session 8: The consequences in perspective: prognosis for the future

Acute radiation sickness and death which occurred early on were limited to a certain group of the personnel working in the nuclear power plant itself and to the fire fighters.

A small increase in certain types of cancer and other health hazards has been recorded for liquidators and those groups of the population which were exposed to the highest doses at the time. With the exception of thyroid cancer, the increase might be due to improved diagnostics or factors other than radiation exposure.

A considerable increase in thyroid cancer was in particular found in people who were children when the accident happened.

For leukaemia, an increase in the number of cases is forecast for the group of people with a high exposure level.

Regarding other types of cancer expected to appear later, there is doubt about whether they ever will be statistically observable.

Apart from the direct effects of radiation exposure, both the breakdown of social structures and considerable stress have become new health hazards. They are connected to the implementation of countermeasures. It is suggested to try new approaches based on the direct involvement of the concerned people, following decentralized decision structures.

PANEL DISCUSSION

The Public's Perception of the Chernobyl Accident

Chairperson

C. LEPAGE
France

EDITORIAL NOTE

The following text of the impromptu discussion was derived by transcription from a recording made at the time of the conference. It has not been edited for substance and content but only to the extent considered necessary for the reader's assistance. Some errors may have occurred during this process, but time limitations have precluded submitting either the transcription or the edited text to the speakers for verification.

The views expressed are not necessarily those of the IAEA.

PANEL DISCUSSION

The Public's Perception of the Chernobyl Accident

Panellists: **Y. Saenko** (Ukraine)
J. Harrison (United Kingdom)
V. Gubarev (Russian Federation)
V. Protchenko (Belarus)
J. Weidemann (Germany)
B. Hanrahan (United Kingdom)
B. Ingham (Sir Bernard Ingham) (United Kingdom)

C. Lepage (Minister of the Environment, France): Madam President, ladies and gentlemen, the aim of this session I will chair is to allow discussion on the differing ways we understand the consequences of the Chernobyl accident, meaning the general public on the one side and on the other side the scientific community. What role in this was played by the press? We shall hear Y. Sayenko from Ukraine, O. Harrison from the United Kingdom, V. Gubarev and V. Protchenko, Russian and Belarusian journalists, O. Weidemann, who is a German journalist based in Kiev, B. Hanrahan from the BBC, and finally Sir Bernard Ingham, the former spokesman of British Prime Minister M. Thatcher. Before giving them the floor, please allow me to say a few words.

In contrast to the early dreams for nuclear energy, since Chernobyl we now have contaminated lands where millions of people live. Those contaminated territories are still used by some for agricultural purposes. There is also psychological stress and associated cardiovascular illnesses. Now, this is important in terms of health and everyone should think what kind of help could be provided for those who still suffer, especially the children.

Since Chernobyl our governments have reacted. Many examples of co-operation were established in order to improve nuclear safety. A thorough analysis of various nuclear technologies used in central and eastern Europe has been carried out, especially with co-operation between France and Germany who played an important role. Significant improvements were brought about. It is well known, however, that the safety level of nuclear power plants in central and eastern Europe does not reach the level of Western plants, and some features of those plants raise serious concerns. Here, let me put the problem which we will discuss now. The best guarantee for safety in nuclear plants in the East as well as in the West is a national, independent safety regulatory body, but public opinion must also be informed. Transparency should be the rule. The industrial sector must be under the control of independent, efficient and reliable bodies. Therefore, privileges resulting from close relationships between the civil nuclear and military nuclear sectors should disappear.

Such awareness is painful but necessary. What we shall talk about is at the heart of the whole matter in human and political terms and therefore I am very happy that I am chairing this panel. I shall now give the floor to Dr. Sayenko.

Y. Saenko (Ukraine): Many years of research in the Sociology Institute of the Ukraine have confirmed that the most unexpected and wide ranging effects of Chernobyl were the social and ecological consequences.

I shall restate the conclusion that the population suffered from three kinds of stress. The first is the stress resulting from the uncertainty which lasted the first three years. In the next three years it was the stress of truth, or the shock of truth, and in the last three years it was the stress from the social and economic crisis, from the devaluation of all kinds of aid that was provided to the ones who suffered. In them we note a lack of orientation for the future, a lack of orientation for life in the present. Most of them say that they suffer endlessly and that the health of their children and their own health has been damaged, and their children therefore also have no future. Many of those who suffer live in the past, that is, live that life which was theirs before Chernobyl. We have also noted that the scale of social damage is considerably greater than the scope of physical damage. The people manifest fatalistic patience. Yet those who are living in the 30 km zone are not worried at all about the operating reactors. They are mainly worried about the sarcophagus. But despite the fact that they actually live next to this source of danger, they have no desire to leave this area. Among the relocated persons approximately 70–80%, and in particular people advanced in age, have a desire to come back to where they lived before. We have noticed a high degree of worry among the population which has not decreased in recent years, and at the same time one could note a certain psychological passivity among them, since a man cannot stay forever in an indeterminate situation and in a state of high stress. There was also a lack among those observed of any degree of initiative, responsibility and activity. That is, a desire to find new models of life. Accordingly, to the criteria of technical needs, medical, and so forth, to them one should add the social criteria. In this room we have noted that even medical investigations and studies do not go as far as social assessment. It is one thing to assess a high morbidity, but behind this we have to see what sort of needs there are for new types of treatment, how many hospital beds are necessary, and in general what sort of requirements there are and compare this with the various Republics and take them individually, and in this fashion compute the social costs involved. What assistance is needed exactly, how it should be applied to alleviate the medical effects, and this hand in hand with alleviation of the social effects.

I think we should leave this stage of separate and differentiated studies and introduce all-encompassing interdisciplinary studies where the same problem ought to be studied by the physicists, by the nuclear scientists, doctors, sociologists, psychologists, in the same team. I consider that the international and national studies should be united into unified programmes. We should also leave a passive research phase. It is not sufficient to simply note what has happened. We should move into an active phase, together. National and international research should be directed at finding models of life for the population that suffered. At any rate, they will live in the same areas where they were going to live so we should find ways of actively involving the population in this activity. I think that simple social and psychological rehabilitation will not provide any result. Allow me to remind you that until the end of 1991, that is during the first five years out of ten that have passed, the problems of Chernobyl were solved in the Soviet Union in an atmosphere of a Communist regime which was subject to ideology and political influences. In the last three and a half years we have been trying to overcome the consequences of two kinds: the consequences of the accident itself and the consequences of political decisions. The problem of politics, scientists and mass media remains open still today and not worked out completely. We have yet to restore the confidence of those who suffered in science, in their own future and in those in power. We also have to rehabilitate, so to speak, those in power in relation to those who suffered.

C. Lepage: Thank you very much for this very interesting presentation. You have spoken about the inter-disciplinary effects and approach which encompasses the social, the economic and the medical.

Now, Dr. Harrison of the United Kingdom, the floor is yours.

J. Harrison (United Kingdom): I am a simple doctor and I have been involved in radiation matters for about 30 years. I would like to be very positive about trying to get messages across to the public. It was clearly a catastrophe, Chernobyl, but the casualties were well treated. We have learnt a lot from that treatment. We have heard in the synopsis that bone marrow transplantation is no longer considered effective. We have learnt more about the combination of medical problems, the difficulties with skin complaints and so on. So it is a very positive message that goes out from my point of view that we have learnt from this catastrophe. We have the problem with the thyroid cancers. If one looks carefully at the Hiroshima and Nagasaki data the latent period for the onset of cancer of the thyroid is 5–6 years. It is normally a rare disease and therefore it is a disease that can be seen quite clearly as a result of this accident. It can be treated and therefore the likelihood of large scale deaths arising from thyroid cancer are really quite low.

We then need to move on to the epidemiology. It is only by diligent and very painstaking research at levels which are considered acceptable in the scientific community that we will be able to establish whether or not extra cancers will actually arise. If I look around this room, and I believe there are about 1000 people at this Conference, 224 of you are going to die of cancer anyway. If you all received 1 Sv of radiation now as a flash dose, 70 more of you *may* possibly die from cancer. So there would be a significant increase. There is no question that members of the public or even the liquidators received such high doses. The probability of finding these cancers is going to be quite difficult. So it is therefore very important that the sort of work that is being sponsored by the European Community and by the WHO for instance be pushed ahead in a coherent manner, and I would like to think that it could actually be co-ordinated so that there is no overlapping of the work. And if we could send these messages out through the press, who really are the Fourth Estate, then I think that instead of gloom and doom we would perhaps be able to say this is being studied and we have learnt some lessons.

But I understand, of course, coming from a Western country, that communication was slightly different in the former Soviet Union. It seems to me that there is a sort of triangle of communication and that communication is only worthwhile if you have the other two links which are trust on the one hand and honesty. And they go together.

I think another important thing that has come out of this Conference, and I think it would be a good message to get across, is that the importance of coherent. well rehearsed countermeasures at nuclear power plants is absolutely paramount. It is quite clear that some of the thyroid cancers could have been prevented had an early distribution of potassium iodine tablets taken place and also if foodstuffs had actually been withdrawn from the food chain. I think there is little doubt about that. But the whole question of countermeasures is a balance. It is a balance between the radiation risk, which is really quite small, and the economic and stress risks on the other side. And so these balances must, it seems to me, be discussed between politicians and scientists so that we actually come to levels which are reasonable. I think it is so important that we have a multidisciplinary approach to the whole question of these countermeasures and that emergency plans are actually developed. It is very important as part of these emergency plans that they be rehearsed and things like, for example, the distribution of iodine tablets is properly discussed and organized.

I don't really want to make a final political point, but I think I will. It seems to me as a scientist that if we look back perhaps in hindsight too little was done too early and too much is being done too late.

C. Lepage: Thank you very much Dr. Harrison for your presentation. I now call upon V. Gubarev, who is a Russian journalist.

V. Gubarev (Russian Federation): I am the first writer and journalist speaking, because scientists have been speaking so far.

I have various doubts in my mind about Chernobyl. I myself originally came from Belarus and indeed very high contamination fell upon my home town. It is highly contaminated. I was the first journalist to arrive in Chernobyl. I was a science journalist, I was the first to work in that area and I worked the entire first difficult month, the most difficult month of my career, in Chernobyl. I have rubbed shoulders with professionals of all sorts, both generals as well as lowly soldiers as well as secretaries-general and presidents, and I well know what picture prevailed at the time. A bit later in June I wrote a play called "Sarcophagus" — it is played around the world — and I have indeed presented the attitude of the community. Basically it is the thinking of people who are lay to the world of physics and atomic energy.

There was indeed ignorance and fear and lies. Never, never in my life have I been faced with such an incredible accumulation of these three things. In Chernobyl I was faced with the totality of lies which was generated not just from this place but also from the West. There was no information in the West and there was data being disseminated that there were 20 000–30 000 people who were fatalities, and it's true this is what would have happened if it had not been stopped short. But what is most important is the lies that were generated in Chernobyl, that were conveyed through the Government in Ukraine which went up to the highest levels of Government and then spread in a ripple effect throughout the countries of the world. On 8 May 1986 I went to Moscow and met with Gorbachev. I was just amazed by the extent to which this leader of the State was not aware of what was known or what was happening in Chernobyl. It was very simple. One wanted to, in addition to the dark picture, try to convey some positive elements and that was distorted in the information system and, given the general lack of knowledge and leadership in the country at large, only the positive facts emerged and nobody believed that things were going askew really badly. And I remember that in 1968 a very famous letter was written in which it was stated that in the Soviet Union at least at the leadership level there should be technically cultured people. I thought that was a very good point, well taken indeed. Many, many scientists at the time behaved very properly, very correctly I must say, and quite honestly I can say that there were many who participated in the liquidation in the three Republics and who are here now. And there are two people, I would like to say these people have been accused of all sorts of things and there are some people who are even considered persona non grata in Ukraine for purely political considerations. They are not even allowed back in Ukraine. But I have been in these government commissions everywhere. I was in on the operational groups and these two persons very totally correctly gave information to the government levels in our country. They are Academicians Ilyin and Izrael, and I would like to thank them for this scientific honesty.

It is true that unfortunately to this day the truth about Chernobyl has not been disseminated and people need only the truth. From this podium I believe that many illusions have been conveyed for example. It is quite clear that this whole illusion of the possible decommissioning of Chernobyl is dangerous. It is very dangerous to shut it down. Neither the economic nor the intellectual power of all of civilization, of human kind, could possibly turn nuclear power plants like Chernobyl into a green pasture again. Even if you shut down the whole power plant in Chernobyl the problem of Chernobyl will remain forever. And with our conversations, our dialogue around Chernobyl we have tried to convey the image that this can take place. It will never take place. This is what should be said quite clearly.

Another thing. The Prime Minister of Ukraine has said that Moscow dictated the nuclear power policy line. That is not the case. I was in on the meetings of the Politburo and there was a fight, a controversy, about where the nuclear power plant should be built because it was felt that this was a good generation of electricity and of health and well being for everybody. And in the Zaporozhe plant work has indeed gone on properly. This should be told to people also.

And then there is fear, and fear is not generated because of atomic energy. It came upon people after Hiroshima and Nagasaki. Fear came upon mankind in August 1945, and no matter what we think we should tell people that atomic energy, nuclear energy, nuclear physics are very dangerous. But what we should consider is the degree of risk, justified or not. And here you have to remember that you are dealing with mass psychology. Take today. If it were just plainly said in this or that village as usual 220 people will get cancer, everybody thinks it is going to be his neighbour, not he, that it's going to happen to. However, if you hear that 220 people out of the liquidator cohort will have this happen to them, each liquidator thinks this is going to be happening to *him*. So it all depends on the mass psychology, and I think that you scientists have to bear this in mind first and foremost when you think in terms of future predictions.

Today there has been reference made to privileges, about the fact that liquidators are people who shouldn't be given certain privileges or benefits. But please, how can you possibly compensate women, girls who were five or six years old at the time? And how could you possibly pay them, for the fact that they cannot get married? Nobody wants to marry these women. The same happened in Japan. These are the women of Chernobyl now. What is going to happen to them? We speak in terms of high words. We say the children of Chernobyl. But do you realize that you are condemning a whole generation of people? That is incredible damage. All right, they are travelling to various countries to seek treatment, but it is as though we are going back to medieval times. It seems to me that we are going back to the times in India where you are calling a certain caste taboo. This is a strategic error. Please remember that. The press, the scientific circles should bear that in mind.

Just one remark in concluding. I would like to say it is my deep conviction that in 1945 man entered a new stage of development, a new civilization dawned upon us. A new era dawned, and this is an era of nuclear physics, nuclear power, nuclear weapons, electronics, and yet our own psychology — human psychology — is still dated BC, before Christ. This is an incredible chasm because it is incredible how the age of ignorance, of necromancy, is upon us, and ignorance is rippling through us and our circles. I believe that because humankind is having to pay so dearly for this difference between our basic culture and the culture of technology that is upon us. Our fate will hinge upon whether we will be able to overcome that chasm.

C. Lepage: Thank you very much V. Gubarev for this very impassioned statement. Now I call on V. Protchenko, also a Russian journalist.

V. Protchenko (Belarus): I would like to say as a word of warning straightaway that my colleagues from Ukraine, Russia and I have essentially come from one country and many of the problems that we have suffered in the past and that we are suffering presently are one and the same. Of course, the emergence of independent States has made a difference, but these differences also have come together and we are regarding these problems now.

I am one of the people who was born at the very limit of the 30 km zone. I was born there, brought up there, educated there and then I went to do my army service. So you can understand how much it hurts me, how much I am concerned to hear about what is happening to my native land. I would like to support what my colleagues have said. Dr. Sayenko has spoken about the stress situation, the stress that has been induced by what happened ten years ago. I would like to say that this also has had an impact on the mass media and has had an impact on our population. Over the past ten years I believe that the media, in the publications, has marked three stages. And in passing I would like to support V. Gubarev when he referred to what can be termed the incomprehensible, possibly ignorant way in which the previous Government behaved.

Certainly the first stage was 1986–1989, and this was marked by super secrecy, a lid was put on events here, and I quite agree with V. Gubarev when he said that there were 18 days of incomprehensible silence on the part of Mikhail Gorbachev. And this super secrecy was then stopped because of the action of democratic forces in our Soviet Union, which in 1991 actually led to the break-up of the Soviet Union. This first stage, 1986–1991, was a period of the eruption of publications, information. There was the emergence of ever so many NGOs and organizations that erupted onto the political scene. And in our Republics now there are more than 100 such organizations. These are organizations which are defending the group interests of the citizens, of nationals who suffered from Chernobyl. You are familiar with these figures. I would like to recall to you that more than 2 million of the citizens of our country, that's one out of every five, suffered and certainly our social organizations which emerged in this period tried to cover those concerns. And of course this activity has had an impact on the decisions that have been taken at the government level.

Then there has been the development and the emergence of independent States in the territory of the former USSR. In the initial stages Russia, Ukraine and Belarus attempted to independently address the Chernobyl problem. However, during the past five days we have noted and become convinced of the fact that this global problem has unpredictable effects and these individual efforts are unable to cope with the globality of this problem, the general all-comprehensive quality of this problem. So this is insufficient.

In conclusion, I would just like to say the following. On behalf of my conationals I would like to stress a very warm "thank you" to all who are helping us to overcome the consequences of Chernobyl. You have helped us with medical support, the drugs that you have helped us to distribute to our population, with socio-psychological effects. The hands of our brethren have been extended to us, and I believe that we have grasped those hands because we believe that this is extremely appreciated. We are going to be doing everything we can so that our country, which has come into such dire straits, so that our children and our grandchildren will be able once again to enjoy it.

C. Lepage: Thank you very much V. Protchenko for this very moving statement. Thank you also very much for your remarks about international co-operation and I think that this will be a mobilizing factor for all of us. I give the floor to J. Weidemann, a German journalist.

J. Weidemann (Germany): When Chernobyl happened I was 21 years old. I wasn't in the zone then, I was in a small village near Mainz, and when the cloud went over our region we were told that there was a nuclear cloud going over our region. So we were told to stay at home. And we stayed at home. Doing research on Chernobyl in Ukraine I now learn that people in Ukraine and people in Belarus were not told about it, and it sometimes robs me of my voice when I think of it. What I will say is exclusively a statement of my own and not of the newspapers I represent, the Neue Zürcher Zeitung and the Handelsblatt.

After visiting Ukraine in 1993 and 1994 I started working as a permanent correspondent in May last year. Since then, an increasing number of friends from Germany and Poland say "You're crazy. What are you doing there? Come home again". This shows how forceful the mass media in the West has influenced the image of Chernobyl and the image of Ukraine and of Belarus as a whole. One example of the power of media: after a private TV station had shown a report on handicapped children and deformed animals, a friend in Germany called me and said "something happened again in the Chernobyl power plant. Don't you know?" I tried to calm her down and said that what she had seen were archive materials and she said "Don't tell me. I have seen it with my own eyes." Some weeks later I occasionally talked to the same person again and she said "Well, it's probably not so bad at Chernobyl. I saw a report about it and a report about the town of Slavutich where the personnel is clean, very decently housed, where children are safe and sound. I saw animals. Everything is OK." I tried to tell the person again that this is the other side, the other extreme of propaganda, and the truth is somewhere between those two extremes.

To understand how media report on Chernobyl you have to know what the situation is at the place, who is on the spot. I would recommend you to distinguish according to the sources of information you get in the West. Those sources are of course Ukrainian news agencies and newspapers, and Ukrainian TV. Their information may lack credibility, it may be propaganda or speculation. Then there are Russian agencies and newspapers. They again often exaggerate negative information about the Chernobyl nuclear power plant and suppress positive information. Then of course there are international correspondents. There are only a few and they are a very good source whenever you want to know how to evaluate information you hear. Lastly, there is the group of "flying in" reporters, and there are masses of them coming in just because of the tenth anniversary of the Chernobyl disaster. It is a pity that they won't fly in any more when the tenth anniversary is over. But maybe we will still live and survive to the twentieth anniversary of the Chernobyl power plant.

International reporting is dominated by the big news agencies, Reuters, AP, DPA and Interfax Russia. As I said, there are only a few press correspondents. Besides Handelsblatt and the Neue Zürcher Zeitung there is a Spiegel correspondent, there is the Wall Street Journal, the Washington Post, and the Financial Times on the spot. Unfortunately, except Reuters TV and the BBC there are almost no permanent TV or radio correspondents in Kiev. The German ARD has recently decided to withdraw their Kiev correspondent and to cover Ukraine again mainly via Moscow.

If you look at the stories you will find about Chernobyl you can distinguish them into several categories. Of course there are human interest stories, and I think it is the best way to cover the problem because if the statistics are unclear and full of contradiction you have to avoid figures because you will otherwise confuse your reader. So don't tell how many children, evacuees and liquidators have exactly died if the figures are anyway subject to manipulation. Just show that most of the liquidators, evacuees or children have been betrayed in April 1986 and still suffer today. Make the disaster visible and don't accept euphemisms like radiophobia, which reminds us of xenophobia and doesn't really give a real sense of the disease. But if you cover the human touch of Chernobyl you don't have to forget to tell the organizations which can help because of course your reports will cause a wave of help or support and people mostly don't know who to address, and this issue is very important because in Ukraine there is a lot of misuse of the label of Chernobyl. There are a lot of organizations just making money for themselves, and we have really to distinguish who to give the money to.

Then there is the public threat stories, and it is certain that even today Chernobyl is a public danger. So every threat report will find public interest and will be printed in the press. This is probably what organizations like the EU and the IAEA are mostly afraid of. This in fact has caused a certain inflation of threat news, mainly "if" news. If water in the Dnieper river rises because of the spring flood, Chernobyl could cause radioactive water pollution that would affect almost 30 million people who drink and use the Dnieper water. This is when my German friends call me and ask why I am still there. But the people in Ukraine are rather indifferent to such information. They are very fatalistic and they are fed up with the Chernobyl power plant. There is a certain "no future" attitude within them, and it is terrible because when you live there you really feel it. You feel it because you ask yourself "can I eat this apple which may be from the region of Chernobyl", "can I buy this salad", "can I drink this milk", and most of the foreigners living in Kiev just buy Western products because they are under stress.

Then there is a third kind of story. The ''poker'' story. This concerns negotiations between the G-7 and Ukraine, to what extent the closure of Chernobyl shall be supported financially. When the negotiations about the closure of Chernobyl were started for the first time the media represented Ukraine as a poker player who doesn't care for the threat of Chernobyl but who wants to make money out of it. This attitude of the media was kept alive also by utterances of Western negotiators. Yet President Kuchma and Minister Kostenko are anything but poker players, and it is what we have to tell the public in the West. They do not play with the lives of people. They look for a pragmatic solution, and this costs money as you have all seen here.

Lastly, the reconstruction of events. Yesterday I had the pleasure to have a look at the book of Mr. Ilyin who is taking a first step towards the documentation of what really happened at Chernobyl. Although mostly Russian experts have tried to publish in areas of the disaster, a lot of questions are still unanswered. To reconstruct the disaster as a journalist seems impossible even today. Journalists have no access to the documentation centres in Moscow, Kiev and Chernobyl. That is why in former times the nuclear power plants were part of the military secrets of these countries, and all information was of course classified. So we can't trace things back to how they really happened. Chernobyl itself has an overshining effect all over Ukraine and Belarus.

Journalists writing about Chernobyl forget about the context. They don't write that there are four more nuclear power plants in Ukraine and what's up with them. There are more RBMK units in the former Soviet Union. How is their performance? I didn't find any article on this. Journalists don't know about the energy crisis of Ukraine, about Ukraine's gas, oil and nuclear fuel dependence on Russia. And they don't know about the energy potentials Ukraine already has, such as wind, water, energy saving. They don't know about the payment crisis, they don't know about the difficulties of the political and economic reform. So Chernobyl is taken out of context. It is shown to the public and, actually, in the West, Ukraine is identified just with Chernobyl and hardly anyone knows anything else about this country. It is almost the same with Belarus. So this would be my appeal, to help journalists to report about Chernobyl, to give them access to documentation. Some of the authorities in Ukraine indeed opened their doors. For instance the Ministry of Nuclear Safety of Mr. Kostenko. Also the power plant itself. Others have not. Before I left Kiev I called the Ministry of Chernobyl, represented here too, to receive a copy of the latest report on the danger of Chernobyl ten years after. In the International Department there is no Press Department available. At the International Department, I was told twice that this is not possible, ''because it is not possible''! I hope that this Conference will change the attitudes of those authorities.

C. Lepage: Thank you very much Mr. Weidemann for this very specific and precise statement of all the difficulties which have to do with providing objective information. I give the floor to B. Hanrahan, BBC.

B. Hanrahan (United Kingdom): On 26 April 1986 I was the BBC correspondent in Moscow. So, along with about another half dozen people who were there at the time, I suppose I can claim to be as responsible as anybody for how the world viewed what happened in those tragic days.

If you want to know why Chernobyl went wrong, why there is an information deficit, why it was an unmitigated public relations disaster, never mind what it was in nuclear terms, you have to go right back to the very first statement. At 9 p.m. on that Monday a four-line statement came out on TASS which included the phrase "measures are being taken to eliminate the consequences of the accident." It was read on Soviet television, the newsreader put the bit of paper down and went on to read the next news story as though that one was of no importance. At that point alarm bells rang everywhere in the world. My first dispatch, which I have here, simply notes what happened and goes on to say how important nuclear energy is in the Soviet Union. The next one, which wasn't very long afterwards, however, had had more time to think about it. It was not a BBC dispatch in the classic form telling people just what was reported. It went on to say "the questions unanswered are the number and seriousness of the casualties, whether they are dead or injured, what sort of damage was done to the nuclear reactor, how widespread was the contamination, when did the accident happen, and what if any plans are there to evacuate the area? Within the Soviet Union the only evidence that this is being viewed seriously is the fact that it is being called an accident rather than a leak and the decision to list the most serious incidents at nuclear plants in the United States, tacitly accepting that this must be at least on a comparable scale." So that was the first that the West made of it. "We have an accident, we don't know what it is, we have a huge list of questions", and a month later I think we still had most of them unanswered.

Ten years later there may be areas we still don't have the answer to because the reflex at that time was not to answer questions or provide information, it was to suppress it and shut down. And that is what happened. I won't bore you with my dispatches over the next few days because they all say much the same thing — there is no further public information. However, on 1 May, for example, the Government statement said "radiation levels are falling, water in the reservoirs is in keeping with normal standards." Reuter at that time reported that students in Kiev were being told not to drink or wash using water. On 3 May, Boris Yeltsin emerges on the scene and starts talking about "some kind of damage, some kind of danger". No one is quite sure. My dispatch at the time notes there must be a political battle at the highest level of Soviet politics. You begin to get a change in the reporting after that. There is the first on-the-spot report from Pravda on 6 May, the first one from Tass on 7 May, but they have a very calming atmosphere. They are talking about no panic, orders being obeyed, evacuation going ahead smoothly, no grounds — an interesting phrase this in Pravda — no grounds for "unwarranted" scepticism. Perhaps some grounds for "warranted" scepticism, one might think. And so it continues. There is supposed to be, and I read Mr. Gubarev's reports in Pravda at that time with great interest, there is supposed to be a change in the reporting, and certainly there is more on-the-spot reporting, but there still remains a complete lack of hard information. It is all rather calming, rather soothing, and it doesn't tell you very much about what's going on, even though at the time we know that the bottom of the reactor was threatening to fall out and burn right through into the groundwater underneath. On 8 May, I find in my notes the first hard figure, a radiation reading reported by Reuter which said "there are 10 to 15 mR at peak at the plant" and then went on to say "there is no danger outside the safety zone" — no idea what the safety zone is. It was all on that level, and I don't think it ever got very much better.

I have also here a communiqué which was issued after the arrival of Dr. Blix on behalf of the International Atomic Energy Agency from the 5th to the 9th of May. It is an interesting document, it is three pages long, it tells you absolutely nothing. It tells you he came, that he was told something, and then he went away again. I think the IAEA were "had" by the Soviet authorities at that time, who effectively used them as part of their cooling, soothing atmosphere. And the reason why we still worry about Chernobyl is because in those very first days we got very frightened, we weren't told anything, and we remain frightened. We still have a fear built into ourselves as a result of how trust was lost right at the very beginning. It was an example of how not to do it. You couldn't get a better example of how to make a mess of something that was already bad. There is no lesson to be drawn from what happened in public relations terms, except to say that is completely the wrong way to do it. You can argue, and this week I suppose you have been looking at the issue "would it have made any practical difference if there had been more information around?" Perhaps there wouldn't have been an accident if secrecy hadn't been endemic, if information had been allowed to pass from one layer to another. The accident might have been treated more quickly, there might not have been the disaster that there was. In psychological terms undoubtedly it did enormous damage, and you have been hearing about the effect since then. People are worried about it, and scientists don't know whether or not to discuss every scare story logically and so risk having them all taken seriously, or to laugh them off and risk being caught by the one that is really serious. There is still a great deal of ignorance in the public and I suspect in a lot of other people's minds as well.

Chernobyl stirs a kind of atavistic fear. It is not what we know now, it's what happened. It is simply the fear that got ingrained in people's brains. It was the same kind of fear that voodoo and witchcraft in times gone by prompted and for exactly the same reason. It is fear of the unknown. People didn't know what happened, they were frightened of what it might lead to and no matter what you do now you are never going to put their brains back together and make them think about it differently. The need in these cases is always — and this is so clear that I don't think anyone would dispute it anymore — for credible, intelligible information. Credible information was not given at the time and the battle was lost right there and then, and has never been recovered. Intelligible information, you must judge for yourself whether or not the kind of scientific information you have been discussing this week is intelligible to the world outside. If it is hotly disputed and argued about, then people aren't necessarily going to understand it. You need to speak with much more of a clear cut common voice about what is going on, particularly on these great fears. Defensive public relations, the idea of putting the best possible gloss on it, simply won't work. That is for politicians trying to project themselves, trying to argue their own case. It is not for public officials giving public information. They must provide the good and the bad alike, and let people make their own minds up. They cannot give people what they think they ought to know and hope they will take from it a better feeling. What they need is information to make their own feelings, but if you lose credibility you never recover it.

There is, however, one other lesson — as I say, I think it's all really so written in letters of fire that everybody knows it — that the concern about this, the concern about the fear of radiation and radioactivity, those buzz words in the modern world that we are all so frightened of, broke through probably the most powerful force I ever came across which is Communist control of information. Not even the war did that. But it was swept away by public concern once that public concern started to be unleashed and be turned on the politicians. It swept away the control of information there, it swept away layers of secrecy in the Soviet Union, and that in turn of course swept away the Soviet Union. No modern State can withstand the kinds of fears that are aroused by things that people don't understand. Very powerful forces, like nuclear power. No modern population is willing to be deprived of the information about it. You have got to give it to them. It is the modern day equivalent I suppose that when people are starving and facing death they will stand up to cavalry charges. If people are frightened for their lives then they will turn on governments and tear them down. That is the power of public perception in this area and it has to be addressed, and it has to be addressed with absolute clarity and honesty.

C. Lepage: Thank you very much for having insisted upon the existence of credible information. I think it shows the need to give all the information, bad or good, and I fully agree. To finish, I give the floor to Sir Bernard Ingham.

Sir Bernard Ingham (United Kingdom): I want to start by registering three broad facts. First Hiroshima put one unit of radioactivity into the atmosphere, two or three if you include Nagasaki. Chernobyl put 400 units into it, and atmospheric nuclear weapons testing in the 50s and the 60s put 40 000 units into the atmosphere. The world survived nuclear tests and therefore will survive Chernobyl. And I think I ought to make this comparative point bearing in mind all the doomsday fantasies I read in British newspapers.

I believe there are three main issues at the moment. First of all making nuclear power as safe as possible, secondly giving proper treatment to those who have fallen ill as a result of Chernobyl, and thirdly, given, sadly, that Chernobyl has occurred, how we can turn it to the benefit of the human race and whether we shall be able to do so properly.

A rational human race, not to mention a rational media, would now be concerned about whether we shall be able to do so properly for the following reasons: the break-up of the Soviet Union; the chaos and economic collapse which has ensued; the dearth of finance and facilities; the lack of information about the populations and "liquidators"; the inferior medical services and records before Chernobyl and the improved monitoring of the population since then; and the economic/political reasons — the compensation industry — for distorting the facts. Our media in Britain seems to find peculiar difficulty in recognizing that the dependency culture could possibly exist in international as well as domestic form. All this adds up to me to the most serious aspect of Chernobyl if you accept that on present knowledge the human race is going to have to rely a great deal more on nuclear energy if the world's rising need for electricity is to be met. Instead, much of the media, the press, radio and television in my own country has been, and remains, preoccupied with writing grossly exaggerated horror stories about Chernobyl, which was bad enough without exaggeration.

Let me give you some examples: the claim that the radioactivity around evacuated children's homes in Chernobyl is so high "that the winter snow melts as fast as it falls" (calculations of the energy required to melt a given amount of snow show that this is a slight exaggeration — by a factor of 26 thousand million); estimates and reports of deaths which have either taken place or will take place range from seven to eight thousand to fifteen million, all from radiation (estimates which owe much to V. Chernosenko, who was received with uncritically open arms by media and anti-nuclear elements in the West, claiming that he was a scientific director of the Chernobyl exclusion zone — he was no such thing.

We have heard this morning the details about the consequences: no excessive leukaemia in the liquidators has yet been found, no observable increase yet in childhood leukaemia in the exposed populations, one health threat which can be linked to radiation (an increase in childhood thyroid cancer), undeniable evidence of the Chernobyl syndrome which causes lassitude and a propensity to blame every slight ailment on Chernobyl. This I suppose is the stress of living with the ignorance and lack of trust which the whole handling of Chernobyl engendered. The real problem is psychological.

Yet what have I read in British newspapers? More than three million people across the country, Ukraine alone, are known to be suffering from the effects of radiation — for which there is no evidence whatsoever. Babies born without limbs, with unspeakable deformities because of radiation — for which there is no evidence whatsoever. No cows wander through the fields, the last horse to be born had eight legs and was hastily put down — again no evidence whatsoever of deformities, not even at the Chernobyl farm where cattle are kept in 30 times normal background radiation (and, incidentally, they were rounded up after roaming free for months in contaminated land immediately after Chernobyl). The wild boar and deer have long since fled. They haven't! The forest is teeming with game because it isn't being hunted. No birds sing in Chernobyl. Spring was bursting out all over when I was there, and a nightingale sang in Opachichi while I was there! No people live there, we are told. Nonsense! I met 61 year old Mrs. Olga Kusherenko who walked back to her beloved peasant holding in the exclusion zone with her 80 year old mother, and a jolly person she was too! When you go there, and recognizing that cancers are likely to get worse before they get better, you will realize that, notwithstanding the cover up and the chaos, it is far from a disaster area, far from a blasted heath. But you don't get this kind of impression from the popular media in my country. All is doom. I am struck by the astounding contrast between the scaremongering of the mass audience, the press, radio and television, broadsheet and tabloid alike, and the medical and scientific journals. You wouldn't think you were living on the same planet. Why? Because of the appalling ignorance of radiation as a natural phenomenon. The media play on public ignorance as well as exposing their own. The commercial nature of the media, the sensation seeking that goes in it. Sensation is a damn sight better commercially than boring, balanced, responsible assessment.

Pressures exist upon journalists, as I know only too well: you don't get your name up in lights, you don't get promotion, you don't get approval for extortionate expenses by being calm, reasoned and responsible, that's not the stuff of which journalistic awards are made! You are suckers for action, for pictures, stunts like from the travelling troubadours of Greenwar, who call themselves Greenpeace. Stunts are their big business. Mould-pouring: the media, with the help of pressure groups, pour certain individuals like myself, I may say, or groups into a mould. Once cast in a certain image you remain so graven for all time. So nuclear is bad and dangerous. But properly controlled not half as dangerous or lethal as the motor car. Only the most traumatic circumstances can break the mould.

And then there is the conspiracy theory of government. Cock-up caused Chernobyl. Conspiracy came later, and that was a cock-up because the wind blew all the radiation into the free West and we all noticed it. There is only one reliable theory of government. It's the cock-up theory! So what is to be done about all this?

Well, let me make two suggestions. I agree absolutely with Brian Hanrahan, we have got to be much more open about all this. But stop sticking the examination of the PR presentational aspects of Chernobyl and similar issues at the end, and as a sort of optional add-on to conferences of this kind. We are dealing primarily with a psychological issue, a presentational PR problem. And secondly, scientists are almost entirely passive in the face of the distortion and the exaggeration about nuclear matters which I have described. Why do they not seek to put it right? Why do they not complain in my country to the various organizations for complaining about press and broadcasting? Why don't they have their own widely circulated rogues gallery of preposterous journalists and pressure groups who have too much of it their own way? We are extremely ill served in my view by the passivity of scientists and by the sensational and irresponsible media as Chernobyl shows and as, indeed now, the Euro-panic over BSE in beef is demonstrating. I have contempt for my sob brothers and sob sisters who write all this bull which devalues journalism and who take uncritically from sources who feed their prejudices. But I have the utmost respect for the gallant few who try to keep things in perspective.

I abhor totalitarian manipulation and cover-up. I glory in a free society in which journalists are free to make fools of politicians and fools of themselves. But I despair, I despair of the long term prospects for freedom when the well of truth is so systematically polluted by those who portray themselves as the White Knights of the independent order of the seekers after eternal verities.

C. Lepage: Thank you, Sir Bernard, for this statement which shows that indeed there is a great diversity of views. During this panel meeting I would like to thank every one of the speakers having contributed. I believe that there is, however, a common denominator: that information is difficult to convey, but that it is indispensable. And it must be credible, because confidence is an absolutely indispensable element. I think that no matter what we all have said, we can all agree on that.

CLOSING SESSION

Chairperson

A. MERKEL
Germany

KEYNOTE CLOSING STATEMENT

A. Merkel
Federal Minister for
Environment, Nature Conservation and Nuclear Safety,
Bonn, Germany

Over the past four days we have dealt with the nuclear power plant disaster of Chernobyl and its consequences. At this point I should like to express my thanks to all those concerned with this conference — the organizers, the rapporteurs, the chairpersons, the participants in discussions — for their efforts and their contribution towards making this conference a success. The presentation and discussion focused on health impacts such as acute radiation effects, thyroid diseases and psychological effects. Also, the effects on the environment, the social and economic consequences as well as issues relating to nuclear safety and to the economic and social effects in the countries concerned were the subjects of discussion. The decisive question is: To what findings has the conference led and under what conditions will the peaceful use of nuclear energy continue to be justifiable?

Before presenting my conclusions, I should like to stress that all delegations consider the 'Highlights of the Conclusions' to be a common platform, but there is still some ground for discussions on individual items.

What are the findings available today on the causes and the radiological consequences of the accident and have we drawn the right conclusions?

CAUSES OF THE ACCIDENT

As to the causes of the accident, there remains no doubt that the accident was due to both human and technical failures. From today's point of view the main causes of the accident were:

- serious deficits as to the physical design of the reactor and the design of the shutdown system;
- a political and organizational system which was not able to eliminate these deficits although they were known for a long time prior to the accident;
- a testing programme which was insufficiently thought out and tested as to its safety and technological aspects;
- a form of management and some operation facilities which placed excessive demand on staff with regard to their responsibility for safety.

Unexpected conditions and events which occurred during the testing programme and which were not anticipated, as well as a lack of information and unforeseen interference of the operating staff provoked a nuclear accident of major severity in which the reactor was totally destroyed within a few seconds. The underlying cause of the reactor disaster in Chernobyl was a major lack of 'safety culture'.

THE CONSEQUENCES OF THE REACTOR ACCIDENT

Owing to the explosion in Unit 4 of the reactor, considerable quantities of the radioactive inventory of the reactor were released. The radiological situation on the site where the accident occurred and in the areas affected by it were determined by the kind and the quantities of released radioactive substances, by the duration of the release and by the weather conditions prevailing there, which were responsible for the dispersion of the contamination.

This led to a considerable exposure of a number of people, initially only in the direct surroundings, later on, though to a lesser extent, also in areas within a distance of several hundred kilometres, and had severe health impacts, in particular on the persons directly affected.

The fire fighters responsible for extinguishing the fire as well as the staff directly on the site of the reactor were exposed to high doses of radiation. A total of 31 persons died within a few weeks.

The decontamination and cleanup work in the region of the exploded reactor was done by army members and civilians from many parts of the Soviet Union. The number of people involved here, which is difficult to define exactly, amounted to about 800 000. This figure also includes persons who participated in the cleanup after the accident, as well as many others, including physicians, teachers and interpreters who worked in the contaminated territories and received on average low doses. Approximately 200 000 liquidators worked in the region of Chernobyl during the period 1986–1987, when the exposures were most significant.

Compared to the fire fighters, these persons were not exposed to the same extremely high doses; nevertheless, they still received substantial radiation doses. Therefore, it would be important to improve our not quite sufficient knowledge about the state of health of these people.

In addition to the direct health impacts, the increase of thyroid cancer, in particular in children, is the most manifest consequence of the disaster. By now, well over 600 cases have become known, the majority of which were registered in Belarus. The incidence of this cancer was unexpected and the type of the carcinoma was unusual. However, an increased rate of leukaemia has not yet been confirmed.

Quite a large number of diseases, which are not considered to be induced by radiation, such as immune deficiency and gastritis, have been clearly on the rise. In addition to the distinct deterioration of general living conditions this increase has to be attributed mainly to the psychosocial realm.

Over 100 000 persons were evacuated right away and some 200 000 were relocated later on. Even today, important areas of Belarus, Ukraine and neighbouring areas of the Russian Federation cannot yet be used for traditional agricultural or forestry purposes.

CONSEQUENCES OF THE ACCIDENT FOR THE FIELD OF RADIATION PROTECTION

Which conclusions have so far been drawn for radiation protection and nuclear safety and which conclusions still have to be drawn for the future?

In the field of radiation protection the studies undertaken so far have made it manifest that despite the considerable knowledge already acquired, there are still deficits where research is urgently needed. The meeting in Minsk in March 1996 gave full evidence of the scientific collaboration between the European Commission and Belarus, Ukraine and the Russian Federation. Also during the topical sessions of this meeting, the effort of the European Union and its Member States was abundantly described. I trust that this collaboration will be continued, since we owe it to the victims of this accident that we expand our knowledge by determined research. Further improvements of the methods used to treat people suffering from radiation ought to be an important part of our efforts. The victims of the accident have demonstrated the importance of prompt and correct diagnosis and therefore undelayed treatment. The existing methods for determining radiation exposure of affected people by biological examinations are not sufficient. Therefore, these methods have to be made more effective and more reliable.

The unexpected incidence of thyroid cancer, in particular among children, and its unusual type show that our radiobiological knowledge of the development of cancer urgently needs to be broadened, in particular in the molecular field. Further research is needed here in order to improve diagnostic methods for cancer recognition and therapeutic procedures for treating cancer on a biological level even at an early stage of its development. Finally, as we could note during the conference, the projected number of affected persons is still determined exclusively by using the Hiroshima and Nagasaki data, and in the light of the experience from the Chernobyl consequences, it has to be questioned if these models apply without any adaptation to different exposure situations. Let us face the facts: it is true that we have been successful in reducing the effects of the accident by disaster control measures. By taking appropriate countermeasures, some of the areas which were used for agricultural purposes and which suffered from radioactive contamination can now be used again. This is an outstanding achievement. However, it is still a far cry from what can be considered a normal situation. Tremendous efforts still have to be made in order to develop appropriate rehabilitation methods.

Also, the accident has caused extensive psychological effects which, with respect to their causes, have to be clearly distinguished from the direct health impacts resulting from radiation exposure. The lack of credibility of experts and political leaders resulted in a feeling of anxiety and the experience of utter helplessness, and social trust was relinquished. Even today it is still hard to re-establish the necessary level of trust and, therefore, a difficult situation continues to prevail. Jointly we have to make every effort to ensure that these people regain a positive perspective for the future.

Therefore, I call upon the international institutions such as the IAEA and the OECD as well as the ICRP to face these facts and to develop concepts for radiation protection in the case of accidents which are geared towards practical implementation. The consequences of radiation protection measures for the population and the people's reaction have to be taken into consideration. Classical post-accident management based on intervention criteria is not sufficient in order to deal appropriately with the complex social situation. We have to establish new framework conditions in order to respond to the psychological situation of people who have to live in lastingly contaminated regions.

INITIATIVES TOWARDS IMPROVING NUCLEAR SAFETY

During the past few years, considerable progress has been achieved in some areas of nuclear safety. In the central and eastern European countries, massive efforts were made in order to eliminate existing deficits of Soviet-style nuclear power plants with regard to safety technology. Also, in many places, efforts were made to increase operational safety and to establish or strengthen independent supervisory and licensing authorities. All these examples represent important steps forward which were made possible with the assistance of the international community.

In this context, the multilateral action programme which was decided upon by the 1992 Economic Summit in Munich and which was confirmed a little later by the G24 States means an important contribution. This action programme continues to be the basis of internationally co-ordinated measures for the improvement of nuclear safety in the countries of central and eastern Europe. Many sides make their contribution here. At a bilateral level these are the individual countries and at an international level these are the financing institutions such as the World Bank and the European Bank for Reconstruction and Development, as well as the European Union within the framework of the TACIS and PHARE Programme and the Euratom loans of the European Investment Bank.

However, the results achieved so far must not be allowed to make us blind to the facts. If we take an honest stance we have to admit that essential goals have not yet been fully reached.

I am well aware that some people will be critical of what I am saying here. Nevertheless, I should like to state very clearly: if we want to make justifiable use of nuclear energy, safety of nuclear power plants has to be given absolute priority. Therefore, safety risks which cannot be accepted have to be eliminated. Where this is not possible, the power plants in question have to be decommissioned. The peaceful use of nuclear energy will only have a future if we observe all internationally recognized safety standards. This is where we all have to make our individual contribution.

In the past few years the international community has supported the countries of central and eastern Europe with services worth several billion US dollars. This support helped to achieve a great deal. Naturally, some of the programmes also have to be viewed critically from today's point of view. West and east first had to develop a working relationship. Further assistance will continue to be required — however, it will always only be help to ensure self-help.

Our common goal must be an international safety partnership which is not restricted to theoretical ideas but proves to be effective in practice. This is the aim we have to pursue. International co-operation is strengthened if it can rely on firm contractual commitments. Let me mention here the Nuclear Safety Convention, which was adopted in 1994 within the framework of the IAEA; only three years after work towards preparing it was started. I call upon all States to ratify this Convention as quickly as possible so that it can enter into force before the end of this year.

All States which accede to this Convention commit themselves to observing basic requirements of nuclear safety and to submitting themselves to an appropriate monitoring process. If we are successful in making this process effective and if we concentrate on the most important safety questions in order to ensure that this process can be implemented in practice, we will make a considerable step forward.

Let me also point out here the Conventions on Early Notification of a Nuclear Accident and on the Assistance in the Case of a Nuclear Accident which were adopted only a little time after the Chernobyl disaster. These two Conventions and quite a few bilateral agreements between countries from east and west which were subsequently concluded, form the basis for the intensive dialogue, which is also possible in the field of nuclear energy.

The toughest discussions took place on the question of what is an acceptable standard of safety, especially with regard to RBMK reactors. In this respect, the conference results are in my opinion a minimum result. Personally, I would have hoped for a stronger statement on the closing down of the Chernobyl reactor as well as of other reactors which do not meet the safety standards required.

We still need further discussion on this, and the successful completion of the Nuclear Summit which will be organized in Moscow next week would mean one step forward. Still existing problems will have to be solved by taking a practical and balanced view. Not mentioning them or even belittling them would not serve any purpose at all. If we succeed in enhancing the co-operation and developing it towards a genuine safety partnership this will be a tremendous success. I take the same view with regard to the Memorandum of Understanding which was agreed late in 1995 by Ukraine and the G7 States in order to reform energy supply in Ukraine and to close down the Chernobyl power plant. Correlated with this we need a lasting and reliable solution for the exploded reactor and the sarcophagus. I call upon all to make their contribution in order to ensure that the Memorandum of Understanding will be successful.

Summing up, I should like to make the following statements. The direct causes which finally provoked the accident in Chernobyl are known today and — as far as we know — have also been eliminated. Although great efforts have been made in some cases, safety deficits which cannot be accepted continue to exist in certain nuclear power plants. These safety deficits have to be eliminated. Where this is not possible, the reactor must not be allowed to continue to operate. Therefore the Nuclear Safety Convention has to enter into force and has to be implemented as quickly as possible.

Even 10 years after the disaster the consequences of radiation due to Chernobyl cannot be completely assessed. Dozens of deaths, hundreds of persons suffering from radiation effects, above all children suffering from thyroid cancer, prompt us to carefully investigate the consequences of radiation on the basis of further scientific research.

The psychological and social consequences of the disaster have been underestimated so far. Hundreds of thousands of people have been affected because they lost their homes, their work or their social networks. Maybe the actual effects of the disaster in the social field have not yet been assessed appropriately. In addition to radiation sensitivity of individuals there also seems to exist some kind of radiation sensitivity of society as a whole.

What happened in Chernobyl is a reason for us to continue to critically ask the question as to the responsible use of nuclear energy. Self-evident answers to these questions are not available. In this context, we also have to take into account the challenge of having to supply an ever increasing population with energy without placing unnecessary burdens on the environment and the climate. The peaceful use of nuclear energy continues to be justifiable if it remains on the basis of an internationally accepted safety level.

The international community has to continue its support for the central and eastern European countries and the people affected by the accident. However, this will always mean help for self-help. Our common goal must be a safety partnership which leads to sustainable use of our energy resources, including nuclear energy.

We have now reached the end of this conference. It was for me an honour and a privilege to serve as President and I should like to express my gratitude to all of you for the co-operation extended to me during the conduct of our business. Last but not least, I should like, on behalf of the conference, to thank the Austrian authorities and the City of Vienna for their hospitality which we enjoyed during this week.

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