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One Decade After Chernobyl:

Summing up the Consequences of the Accident

Summary of the Conference Results

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Background information

This is a summary of the results of the Joint EC/IAEA/WHO International Conference "One Decade after Chernobyl: Summing up the Consequences of the Accident," held in Vienna, 8–12 April 1996. It 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.

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

This summary does not necessarily reflect the views of governments of member states of the sponsoring organizations.

Summary of the Conference Results

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

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.

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 fire-fighters, 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.

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]

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.

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

[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).*

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: ~1.3 - 1.8 x 10^{18} Bq; ^{134}Cs: ~0.05 x 10^{18} Bq; ^{137}Cs: ~0.09 x 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

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 territories of Belarus, Russia and Ukraine in which activity levels of ^{137}Cs in excess of 185 kBq/m2 were measured were estimated at 16500 km2, 4600 km2 and 8100 km2 respectively.

Radiation doses

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 dosen people who responded initially to the accident received potentially lethal doses of a few thousands of millisieverts.

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.

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.

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

[2]The quantity radiation dose is 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 x 70 ≈ 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.

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

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.

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.

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

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.

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.

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.

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.

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.

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.

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 favorably 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.

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

[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.*

incidence of thyroid carcinoma in adults who received high radiation doses as children.

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

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.

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.

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.

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.

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

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.

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.

The lack of consensus about the accidents 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.

There is an urgent need to foster trust in the personal ability to change ones 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

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.

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.

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.

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 are the most appropriate countermeasures 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.

The semi-natural 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 137Cs 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.

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

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.

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.

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.

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.

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.

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 accidents consequences and on measures for their alleviation.

Nuclear safety

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 of before the accident.

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.

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.

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 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.

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.

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.

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

[5]*The Safety of Nuclear Power: Strategy for the Future (Proceedings of Conference, Vienna, 2-6 September 1991), IAEA, Vienna (1992).*

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; and

- the status of national regulatory authorities and their support organizations must be strengthened.

Similar backfits as 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.

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

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 x 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 a worst case, widespread effects (beyond 30 km away) would not be expected.

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.

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.

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.

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

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.

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.

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.

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.

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.

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.

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.

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.

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 still further to the public 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.