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Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts

and

Recommendations to the Governments of Belarus, the Russian Federation and Ukraine

The Chernobyl Forum

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IAEA

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Highlights of the Chernobyl Forum Studies

Nearly 20 years after the Chernobyl nuclear power plant (NPP) accident, many questions remained unanswered regarding the health, environmental, and socio-economic consequences of the disaster. The individuals and countries most affected had yet to obtain a clear scientific consensus on the impact of the accident and authoritative answers to outstanding questions. To fill this void and to promote better understanding and improved measures to deal with the impacts of the accident, the Chernobyl Forum was established in 2003.

The Chernobyl Forum is an initiative of the IAEA, in cooperation with the WHO, UNDP, FAO, UNEP, UN-OCHA, UNSCEAR, the World Bank[1] and the governments of Belarus, the Russian Federation and the Ukraine. The Forum was created as a contribution to the United Nations' ten-year strategy for Chernobyl, launched in 2002 with the publication of *Human Consequences of the Chernobyl Nuclear Accident — A Strategy for Recovery*.

To provide a basis for achieving the goal of the Forum, the IAEA convened an expert working group of scientists to summarize the environmental effects, and the WHO convened an expert group to summarize the health effects and medical care programmes in the three most affected countries. The information presented here and in the two full expert group reports has been drawn from scientific studies undertaken by the IAEA, WHO, UNSCEAR and numerous other authoritative bodies. In addition, UNDP has drawn on the work of eminent economists and policy specialists to assess the socio-economic impact of the Chernobyl accident, based largely on the 2002 UN study as above.

[1] International Atomic Energy Agency (IAEA), World Health Organization (WHO), United Nations Development Programme (UNDP), Food and Agriculture Organization (FAO), United Nations Environment Programme (UNEP), United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Preface: The Chernobyl Accident

The explosions that ruptured the Chernobyl reactor vessel and the consequent fire that started on April 26, 1986 and continued for 10-days resulted in an unprecedented release of radioactive materials to the environment. Indeed, the IAEA characterized the event as the “foremost nuclear catastrophe in human history.”

The cloud from the burning reactor spread numerous types of radioactive materials, especially iodine and caesium radionuclides, over much of Europe. Radioactive iodine-131, most significant in contributing to thyroid doses, has a short half-life (8 days) and largely disintegrated within the first few weeks of the accident. Radioactive caesium-137, which contributes to both external and internal doses, has a much longer half-life (30 years) and is still measurable in soils and some foods in many parts of Europe, see Fig. 1. The greatest concentrations of contamination occurred over large areas of the Soviet Union surrounding the reactor in what are now the countries of Belarus, the Russian Federation and the Ukraine.

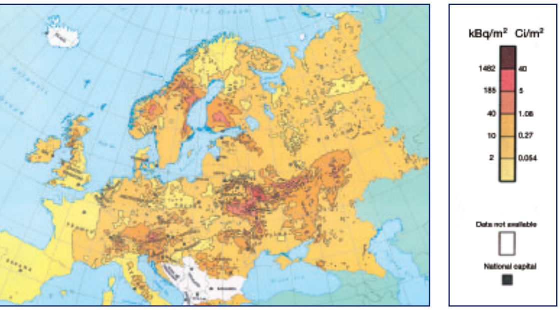


FIG. 1. Surface-ground deposition of ^{137}Cs throughout Europe as a result of the Chernobyl accident (De Cort et al. 1998).

An estimated 200 000 emergency and recovery operation workers from the army and volunteers, power plant staff, local police and fire services were initially involved in containing and cleaning up the accident in 1986–1987. Later, the number of registered “liquidators” rose to 600 000, although only a small fraction of these were exposed to dangerous levels of radiation. The highest doses were received by emergency workers and on-site personnel, in total about 1000 people, during the first day of the accident.

About five million people live in areas of Belarus, Russia and Ukraine that are contaminated with radionuclides due to the Chernobyl accident (above 37 kBq m^{-2} of ^{137}Cs)[2]. Amongst them, about 400 000 people lived in more contaminated areas — classified by Soviet authorities as areas of strict control (above 555 kBq m^{-2} of ^{137}Cs). Of this population, 116 000 people were

[2] Becquerel (Bq) is the international unit of radioactivity equal to one nuclear decay per second.

evacuated in the spring and summer of 1986 from the area surrounding the Chernobyl power plant (designated the "Exclusion Zone") to non-contaminated areas.

Unfortunately, reliable information about the accident and the resulting radioactive contamination was unavailable initially to the affected people in what was then the Soviet Union and remained inadequate for about two years following the accident. This failure and delay led to widespread distrust of official information and the mistaken attribution of many ill health conditions to radiation exposure.

Health Consequences: Forum Expert Group Report

The report of the Expert Group on health consequences responds to five of the most important health-related questions concerning the impact of the Chernobyl accident.

How much radiation were people exposed to as a result of the accident?

Three population categories were exposed from the Chernobyl accident:

— Emergency and recovery operation workers who worked at the Chernobyl power plant after the accident;

— Inhabitants evacuated from contaminated areas; and

— Inhabitants of contaminated areas who were not evacuated.

With the exception of the on-site reactor personnel and the emergency workers who were present near the destroyed reactor during the time of the accident and shortly afterwards, most of recovery operation workers and people living in the contaminated territories received relatively low whole-body radiation doses, comparable to background radiation levels.

Some of the reactor staff and emergency workers received, on 26 April 1986, high doses of external gamma radiation estimated to vary from 2 to 20 Gy, and as a result 28 of them died within first four months from radiation and thermal burns, and another 19 died over the years up to 2004. The doses received by recovery operation workers, who worked for short period during four years following the accident ranged up to about 500 mSv, with an average of about 100 mSv according to the State Registries of Belarus, Russia, and Ukraine.

Doses of Ionizing Radiation

Interaction of ionizing radiation (alpha, beta, gamma and other kinds of radiation) with living matter may damage human cells, causing death to some and modifying others. Exposure to ionizing radiation is measured in terms of absorbed energy per unit mass, i.e., absorbed dose. The unit of absorbed dose is the gray (Gy), which is a joule per kilogram (J/kg). The absorbed dose in a human body of a few grays may cause acute radiation syndrome (ARS) as happened with some of the Chernobyl emergency workers.

Because many organs and tissues were exposed as a result of the Chernobyl accident, it has been very common to use an additional concept, that of effective dose, which characterizes the overall health risk due to any combination of radiation. The effective dose accounts both for absorbed energy and type of radiation and for susceptibility of various organs and tissues to development of a severe radiation-induced cancer or genetic effect. Moreover, it applies equally to external and internal exposure and to uniform or non-uniform irradiation The unit of effective dose is the sievert. One sievert is a rather large dose and so the millisievert or mSv (one thousandth of a Sv) is commonly used to describe normal exposures.

Living organisms are continually exposed to ionizing radiation from natural sources, which include cosmic rays, cosmogenic and terrestrial radionuclides (such as ^{40}K, ^{238}U, ^{232}Th and their progeny including ^{222}Rn (radon)). UNSCEAR has estimated annual natural background doses of humans worldwide to average 2.4 mSv, with a typical range of 1–10 mSv. Lifetime doses due to natural radiation would thus be about 100–700 mSv. Radiation doses to humans may be characterized as low-level if they are comparable to natural background radiation levels of a few mSv per year.

Exposure levels of the evacuees from the Chernobyl accident area were also of concern. Doses that could only be estimated some time after they occurred by careful evaluation of all available information were 17 mSv on average to Ukrainian evacuees, with doses to individuals ranging from 0.1 to 380 mSv. The average dose to Belarusian evacuees was 31 mSv, with the highest average dose in two villages being about 300 mSv.

Ingestion of food contaminated with radioactive iodine did result in significant doses to the thyroid of inhabitants of the contaminated areas of Belarus, Russia, and Ukraine. The thyroid doses varied in a wide range, according to age, level of ground contamination with ^{131}I, and milk consumption rate. Reported individual thyroid doses ranged up to about 50 Gy, with average doses in contaminated areas being about 0.03 to 0.3 Gy, depending on the region where people lived and on their age. The thyroid doses to residents of the Pripyat city located in the vicinity of the Chernobyl power plant, were substantially reduced by timely distribution of stable iodine tablets. Drinking milk from cows that ate contaminated grass immediately after the accident was one of the main reasons for the high doses to the thyroid of children, and why so many children subsequently developed thyroid cancer.

The general public has been exposed during the past twenty years after the accident both from external sources (^{137}Cs on soil, etc.) and via intake of radionuclides (mainly, ^{137}Cs) with foods, water and air, see Fig. 2. The average effective doses for the general population of contaminated areas accumulated in 1986–2005 were estimated to be between 10 and 20 mSv in various regions. Some residents received up to some hundred mSv, and others received lower doses.
It should be noted that the average doses received by residents of the territories contaminated by Chernobyl fallout are generally lower than those received by people who live in well known areas of high natural background radiation in India, Iran, Brazil and China. Some residents in these areas receive over 25 mSv per year from the radioactive materials in the soil on which they live without any apparent health effects.

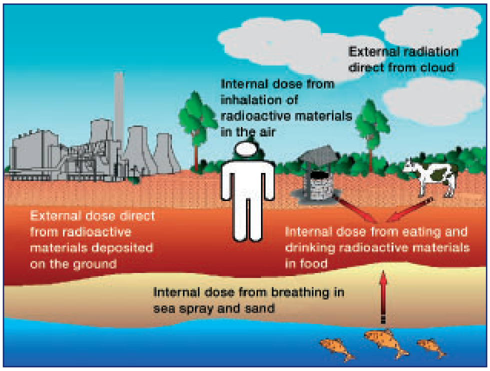


FIG. 2. Pathways of exposure to man from environmental releases of radioactive materials.

The vast majority of about five million people residing in contaminated areas of Belarus, Russia and Ukraine currently receive annual effective dose from the Chernobyl fallout of less than 1 mSv (a recommended dose limit for the general public). However, about 100 000 residents of the more contaminated areas still receive more than 1 mSv annually. Although future reduction of exposure levels is expected to be rather slow, i.e. of about 3 to 5% per year, the great majority of dose from the accident has already been accumulated.

The Chernobyl Forum assessment agrees with that of the UNSCEAR 2000 Report in terms of the individual and collective doses received by the populations of the three most affected countries: Belarus, Russia and Ukraine.

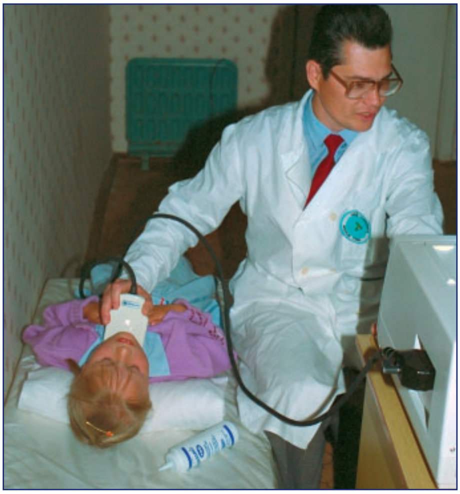
How many people died from the accident and how many more are likely to die?

The number of deaths attributable to the Chernobyl accident has been of paramount interest to the general public, scientists, the mass media, and politicians. Claims have been made that tens or even hundreds of thousands of persons have died as a result of the accident. These claims are exaggerated: the total number of people that could have died or could die in the future due to Chernobyl originated exposure over the lifetime of emergency workers and residents of most contaminated areas is estimated to be around 4 000. This total includes some 50 emergency workers who died of acute radiation syndrome (ARS) in 1986 and other causes in later years; 9 children who died of thyroid cancer; and an estimated 3 940 people that could die from cancer contracted as a result of radiation exposure. The latter number accounts for the 200 000 emergency and recovery operation workers from 1986–1987, 116 000 evacuees, and 270 000 residents of most contaminated areas.

Confusion about the impact of Chernobyl has arisen owing to the fact that, in the years since 1986, thousands of emergency and recovery operation workers as well as people who lived in contaminated territories have died of diverse natural causes that cannot be attributed to radiation. However, widespread expectations of ill health and a tendency to attribute all health problems to exposure to radiation have led local residents to assume that Chernobyl-related fatalities were much higher.

The number of deaths due to ARS during the first year following the accident is well documented. According to UNSCEAR (2000), ARS was originally diagnosed in 237 reactor and emergency workers but later confirmed with detailed clinical analysis in 134 persons. In many cases the ARS was complicated by extensive beta radiation skin burns and sepsis. Among these workers, 28 persons died in 1986 due to ARS, and 19 more persons died in 1987–2004 of various causes. Long term radiation-caused illness may have led to the deaths of some ARS survivors during the subsequent years. Among the general population affected by the Chernobyl radioactive fallout, however, the radiation doses were quite low, and ARS and associated fatalities did not occur.

By contrast, the number of deaths over the past 20 years that may have been attributable to the accident are only estimates with a moderately large range of uncertainty. The reason for this uncertainty is that people who received additional doses of low-level radiation have been dying from the same causes as unaffected people. Moreover, in all the groups studied, of both emergency workers and resident populations, any increase in mortality as compared to control groups was statistically insignificant or very low. Estimates related to projected deaths in the future are even less certain, as they are subject to other major confounding factors. In reality, the actual number of deaths caused by the accident is unlikely ever to be known with precision.



In addition to the ARS deaths, experts from different countries intensively studied mortality among emergency and recovery operation workers as well as among populations of contaminated areas in Belarus, Russia and Ukraine. Direct radiation-epidemiological studies performed since 1986 have so far revealed no radiation-induced increase in the mortality of the general population, in particular caused by leukaemia and solid cancers (other than thyroid cancer in children) or non-cancer diseases above the spontaneous level. The documented deaths from thyroid cancer in children and adolescents in the three countries presently number nine.

Some radiation-induced increase in morbidity and mortality caused specifically by leukaemia, solid cancers and circulatory system diseases has been reported in Russian emergency and recovery operation workers. According to the data of the Russian Registry, about 5% of fatalities that occurred in 1991–1998 in the cohort under study of 61 000 Russian workers exposed to an average dose of 107 mSv can be caused by radiation-induced diseases. The absolute number of deaths in this cohort attributable to radiation caused by solid cancers, circulatory system diseases and leukaemia was estimated to be about 230 cases.

What diseases have already resulted or might occur in the future from the Chernobyl radiation exposure?

Thyroid Cancer in Children

One of the principal radionuclides released by the Chernobyl accident was iodine-131. The thyroid gland accumulates iodine from the blood stream as part of its normal metabolism. Therefore, fallout of radioactive iodines led to considerable thyroid exposure of local residents through inhalation and ingestion of contaminated foodstuffs, especially milk. The thyroid gland is one of the organs most susceptible to cancer induction by radiation. Children were found to be the most vulnerable population, and a substantial increase in thyroid cancer among those exposed as children was recorded subsequent to the accident.

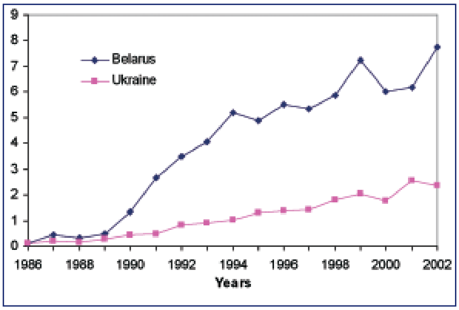


FIG. 3. Incidence rate of thyroid cancer in children and adolescents exposed to ^{131}I as a result of the Chernobyl accident (Jacob et al., 2005).

Between 1992–2000 in Belarus, Russia and Ukraine about 4000 cases of thyroid cancer were diagnosed among those who were children and adolescents (0–18 years) at the time of the accident, including about 3000 in the age group 0–14 years, see Fig. 3.

For the 1152 thyroid cancer cases diagnosed among children in Belarus during 1986–2002 and treated, the survival rate was 98.8%. Eight patients (0.7%) died due to progression of the thyroid cancer, and 6 children (0.5%) died from other causes. One patient with thyroid cancer died in Russia. Taking into account the substantial risk of thyroid cancer in children and adolescents and the high thyroid doses received, we can be reasonably certain that most of the thyroid cancer incidence can be attributed to radiation.

Leukaemia, Solid Cancers and Circulatory Diseases

Ionizing radiation is an established cause of certain types of cancer, i.e. both leukaemia (except CLL[3]) and solid cancers. Exposure of different populations to high doses as a result of the atomic bombings of Hiroshima and Nagasaki and accidents, or as part of diagnosing or treating disease, has been associated with increased cancer incidence and

[3] CLL is Chronic Lymphoid Leukaemia that is not thought to be caused by radiation exposure.

mortality. Recently, a slight increase in the remote incidence of cardiovascular diseases attributable to radiation at higher doses has been observed in some study groups.

Because of differing doses received, an increased risk of *leukaemia* associated with radiation exposure from Chernobyl may become evident for higher exposed emergency and recovery operation workers but would be quite unlikely for the general population.

The most recent studies suggest a two-fold increase in the incidence of non-CLL leukaemia between 1986 and 1996 in Russian emergency and recovery operation workers exposed to more than 150 mGy (external dose). On-going studies of the workers may provide additional information on the possible increased risk of leukaemia. However, since the risk of radiation-induced leukaemia decreases several decades after exposure, its contribution to morbidity and mortality is likely to become less significant as time progresses.

There have been many post-Chernobyl studies of leukaemia morbidity in the populations of areas contaminated with radionuclides in the three countries. There is no convincing evidence that the incidence of leukaemia has increased in children or adult residents of the exposed populations in Russia and Ukraine.

There appears to be some recent increase in Russian emergency and recovery operation workers morbidity and mortality caused by *solid cancers and possibly circulatory system diseases*. Incidence of circulatory system diseases should be interpreted with special care because of the possible indirect influence of confounding factors, such as stress and unhealthy lifestyle.

Because of the generally low doses received, however, there remains a lack of evidence of any measurable effect of Chernobyl radiation exposures on solid cancers in the general population except for childhood thyroid cancer, since higher doses to the thyroid gland were received by children in contaminated areas.

It is well known from long term epidemiological studies (such as the atomic-bomb survivors) that elevated radiation-induced solid cancer morbidity is sustained for decades after exposure, following a latency period of about ten years. Therefore, medical care and annual examinations of highly exposed Chernobyl workers should continue.

Cataracts

Examinations of eyes of children and emergency and recovery operation workers clearly show that cataracts may develop in association with exposure to radiation from the Chernobyl accident. The data from studies of emergency and recovery workers suggest that exposures to doses somewhat lower than previously experienced, down to about 250 mGy may be cataractogenic.

Continued eye follow-up studies of the Chernobyl populations will allow greater predictive capability of the risk of radiation cataract onset and, more importantly, provide the data necessary to be able to assess the likelihood of any resulting visual dysfunction.

Have there been or will there be any inherited or reproductive effects?

Because of the relatively low dose levels to which the population of the Chernobyl-affected regions was exposed, there is no evidence nor any likelihood of observing decreased fertility among males or females in the general population as a direct result of radiation exposure. These doses are also unlikely to have any effect on the number of stillbirths, adverse pregnancy outcomes, delivery complications or the overall health of children.

Birth rates may be lower in contaminated areas because of concern about having children, and this issue is obscured by the very high rate of medical abortions. No discernable increase in hereditary effects caused by radiation is expected based on the low risk coefficients estimated by UNSCEAR (2001) or in previous reports on Chernobyl health effects. Since 2000, there has been no new evidence provided to change this conclusion.

There has been a modest but steady increase in reported congenital malformations in both contaminated and uncontaminated areas of Belarus since 1986, see Fig. 4. This does not appear to be radiation-related and may be the result of increased registration.

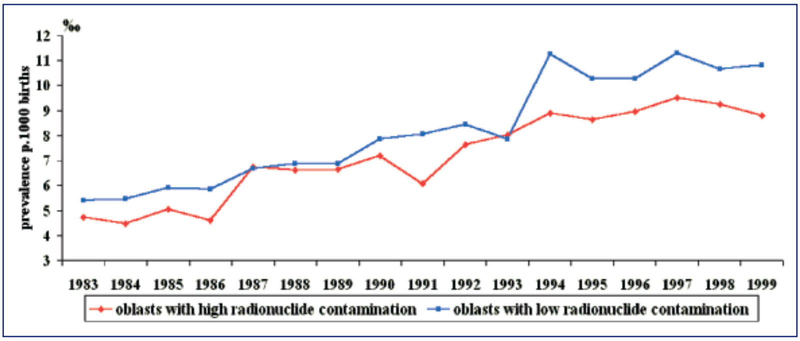


FIG. 4. Prevalence at birth of congenital malformations in 4 oblasts of Belarus with high and low levels of radionuclide contamination (Lazjuk et al., 1999).

Many people were traumatized by the rapid relocation, the breakdown in social contacts, fear and anxiety about what health effects might result. Are there persistent psychological or mental health problems?

Any traumatic accident or event can cause the incidence of stress symptoms, depression, anxiety (including post-traumatic stress symptoms), and medically unexplained physical symptoms. Such effects have also been reported in Chernobyl-exposed populations. Three studies found that exposed populations had anxiety levels that were twice as high as controls, and they were 3–4 times more likely to report multiple unexplained physical symptoms and subjective poor health than were unaffected control groups.

In general, although the psychological consequences found in Chernobyl exposed populations are similar to those in atomic-bomb survivors, residents near the Three Mile Island nuclear power plant accident, and those who experienced toxic exposures at work or in the environment, the context in which the Chernobyl accident occurred makes the findings difficult to interpret because of the complicated series of events unleashed by the accident, the multiple extreme stresses and culture-specific ways of expressing distress.

In addition, individuals in the affected population were officially given the label "Chernobyl victims", thus frequently taking on the role of invalids. It is known that if a situation is perceived as real, it is real in its consequences. Thus rather than perceiving themselves as "survivors," the affected individuals have been encouraged to perceive themselves as helpless, weak and lacking control over their future.

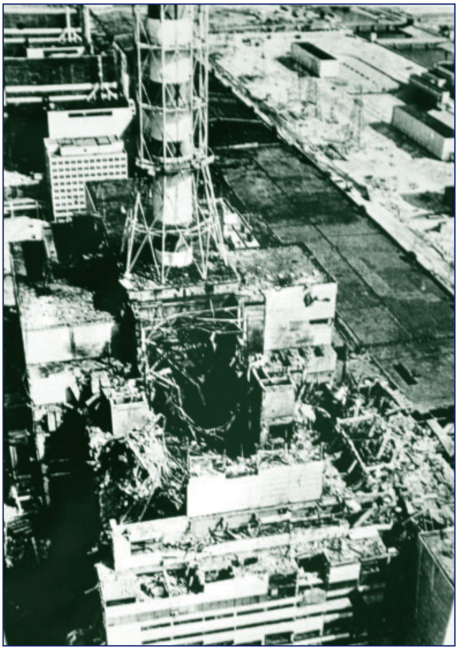
Renewed efforts at risk communication, providing the public and key professionals with accurate information about the health and mental health consequences of the disaster, should be undertaken.

Environmental Consequences: Forum Expert Group Report

The report of the Expert Group on environmental consequences covers the issues of radioactive release and deposition, radionuclide transfers and bioaccumulation, application of countermeasures, radiation-induced effects on plants and animals as well as dismantlement of the Shelter and radioactive waste management in the Chernobyl Exclusion Zone.

Release and Deposits of Radioactive Material

Major releases of radionuclides from unit 4 of the Chernobyl reactor continued for ten days following the April 26 explosion. These included radioactive gases, condensed aerosols and a large amount of fuel particles. The total release of radioactive substances was about 14 EBq[4], including 1.8 EBq of iodine-131, 0.085 EBq of ^{137}Cs, 0.01 EBq of ^{90}Sr and 0.003 EBq of plutonium radioisotopes. The noble gases contributed about 50% of the total release.



More than 200 000 square kilometres of Europe were contaminated above the level of 37 kBq m^{-2} of ^{137}Cs. Over 70 percent of this area was in the three most affected countries, Belarus, Russia and Ukraine. The deposition was extremely varied, as it was enhanced in areas where it was raining when the contaminated air masses passed. Most of the strontium and plutonium radioisotopes were deposited within 100 km of the destroyed reactor due to larger particle sizes.

Many of the most significant radionuclides had short physical half-lives. Thus, most of the radionuclides released by the accident have decayed away. The releases of radioactive iodines caused great concern immediately after the accident. For the decades to come ^{137}Cs contamination will continue to be of greatest importance, with secondary attention to ^{90}Sr. Over the longer term (hundreds to thousands of years) the radionuclide contamination expected to be of significant interest is that involving plutonium isotopes and americium-241.

What is the scope of urban contamination?

Open surfaces in urban areas, such as lawns, parks, streets, roads, town squares, building roofs and walls, were the most heavily contaminated with radionuclides. Under dry conditions, trees, bushes, lawns and roofs initially became more contaminated, whereas under wet conditions horizontal surfaces, such as soil plots and lawns, received the highest initial contamination. Enhanced ^{137}Cs concentrations were found around houses where the rain had transported the radioactive material from the roofs to the ground.

[4] 1 EBq = 10^{18} Bq (Becquerel).

The deposition in urban areas in the nearest city of Pripyat and surrounding settlements could have initially given rise to a substantial external dose. However, this was to a large extent averted by the timely evacuation of residents. The deposition of radioactive material in other urban areas has resulted in various levels of radiation exposure to people in subsequent years and continues to this day.

Due to wind and rain and human activities, including traffic, street washing and cleanup, surface contamination by radioactive materials has been reduced significantly in inhabited and recreational areas during 1986 and afterwards. One of the consequences of these processes has been secondary contamination of sewage systems and sludge storage.

At present, in most of the settlements subjected to radioactive contamination as a result of Chernobyl, the air dose rate above solid surfaces has returned to the background level predating the accident. But the air dose rate remains elevated above undisturbed soil in gardens, kitchen-gardens and parks in some settlements of Belarus, Russia and Ukraine.

How contaminated are agricultural areas?

In the early months after the accident, contamination of agricultural plants and plant-consuming animals was dominated by surface deposits of radionuclides. The deposition of radioiodine caused the most immediate concern, but the problem was confined to the first two months after the accident because of fast decay of the most important isotope, ^{131}I.

The radioiodine was rapidly absorbed into milk at a high rate leading to significant thyroid doses to people consuming milk, especially children in Belarus, Russia and Ukraine. In the rest of Europe increased levels of radioiodine in milk were observed in some contaminated southern areas, where dairy animals were already outdoors.

After the early phase of direct contamination, uptake of radionuclides through plant roots from soil became increasingly important. Radioisotopes of caesium (^{137}Cs and ^{134}Cs) were the nuclides which led to the largest problems, and even after decay of ^{134}Cs (half-life of 2.1 years) by the mid-1990s the levels of longer lived ^{137}Cs in agricultural products from highly affected areas still may require environmental remediation. In addition, ^{90}Sr could cause problems in areas close to the reactor, but at greater distances its deposition levels were low. Other radionuclides such as plutonium isotopes and ^{241}Am did not cause real problems in agriculture, either because they were present at low deposition levels, or were poorly available for root uptake from soil.

In general, there was a substantial reduction in the transfer of radionuclides to vegetation and animals in intensive agricultural systems in the first few years after deposition, as would be expected due to weathering, physical decay, migration of radionuclides down the soil and reductions in bioavailability in soil, see Fig. 5. However, in the last decade there has been little further obvious decline, by 3–7 percent per year.

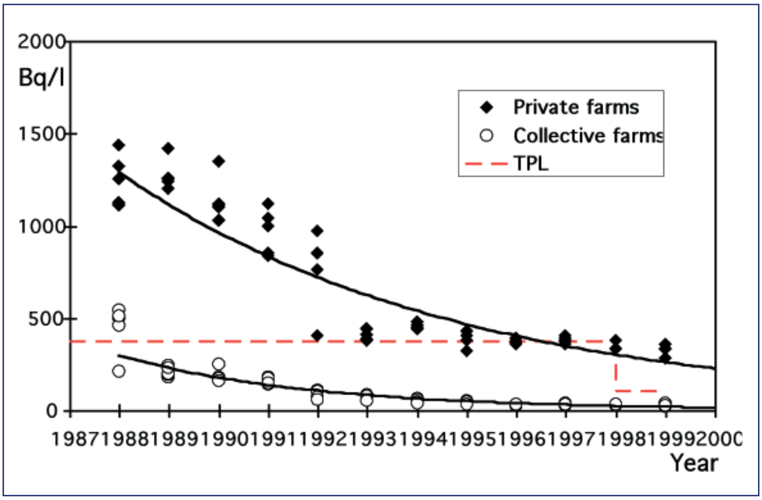


FIG. 5. Reduction with time of 137Cs activity concentration in milk produced in private and collective farms of the Rovno region of Ukraine with a comparison to the temporary permissible level (TPL).

The radiocaesium content in foodstuffs was influenced not only by deposition levels but also by types of ecosystem and soil as well as by management practices. The remaining persistent problems in the affected areas occur in extensive agricultural systems with soils with a high organic content and animals grazing in unimproved pastures that are not ploughed or fertilized. This particularly affects rural residents in the former Soviet Union who are commonly subsistence farmers with privately owned dairy cows.

In the long term ^{137}Cs in milk and meat and, to a lesser extent, ^{137}Cs in plant foods and crops remain the most important contributors to human internal dose. As ^{137}Cs activity concentration in both vegetable and animal foods has been decreasing very slowly during the last decade, the contribution of ^{137}Cs to internal dose will continue to dominate for decades to come. The importance of other long lived radionuclides, ^{90}Sr, plutonium isotopes and ^{241}Am, in terms of the human dose will remain insignificant.

Currently, ^{137}Cs activity concentrations in agricultural food products produced in areas affected by the Chernobyl fallout are generally below national and international action levels. However, in some limited areas with high radionuclide contamination (parts of the Gomel and Mogilev regions in Belarus and the Bryansk region in Russia) or poor organic soils (the Zhytomir and Rovno regions in the Ukraine) milk may still be produced with ^{137}Cs activity concentrations that exceed national action levels of 100 Bq per kilogram. In these areas environmental remediation may still be warranted.

What is the extent of forest contamination?

Following the accident vegetation and animals in forests and mountain areas have shown particularly high uptake of radiocaesium, with the highest recorded ^{137}Cs levels found in forest food products. This is due to the persistent recycling of radiocaesium particularly in forest ecosystems.

Particularly high ^{137}Cs activity concentrations have been found in mushrooms, berries, and game, and these high levels have persisted for two decades. Thus, while the magnitude of human exposure through agricultural products has experienced a general decline, high levels of contamination of forest food products have continued and still exceed intervention levels in many countries. In some areas of Belarus and Russia, consumption of forest foods with ^{137}Cs dominates internal exposure. This can be expected to continue for several decades.

Therefore, the relative importance of forests in contributing to radiological exposures of the populations of several affected countries has increased with time. It will primarily be the combination of downward migration in the soil and the physical decay of ^{137}Cs that will contribute to any further slow long term reduction in contamination of forest food products.

The high transfer of radiocaesium in the pathway lichen-to-reindeer meat-to-humans has been demonstrated again after the Chernobyl accident in the Arctic and sub-Arctic areas of Europe. The Chernobyl accident led to high contamination of reindeer meat in Finland, Norway, Russia and Sweden and caused significant problems for the indigenous Sami people.

How contaminated are the aquatic systems?

Radioactivity from Chernobyl contaminated surface water systems in areas close to the reactor site and in many other parts of Europe. The initial contamination was due primarily to direct deposition of radionuclides on the surface of rivers and lakes, dominated by short lived radionuclides (primarily ^{131}I). In the first few weeks after the accident, high activity concentrations in drinking water from the Kyiv Reservoir were of particular concern.

Contamination of water bodies fell rapidly during the weeks after fallout through dilution, physical decay and absorption of radionuclides to catchment soils. Bed sediments are an important long term sink for radioactivity.

Initial uptake of radioiodine to fish was rapid, but activity concentrations declined quickly, due primarily to physical decay. Bioaccumulation of radiocaesium in the aquatic food chain led to significant activity concentrations in fish in the most affected areas, and in some lakes as far away as Scandinavia and Germany. Because of generally lower fallout and lower bioaccumulation, ^{90}Sr levels in fish were not significant for human doses in comparison to radiocaesium, particularly since ^{90}Sr is accumulated in bone rather than in edible muscle.

In the long term, secondary contamination by runoff of long lived ^{137}Cs and ^{90}Sr from contaminated soils continues (at a much lower level) to the present day. At the present time, activity concentrations both in surface waters and in fish are low, see Fig. 6. Therefore, irrigation with surface water is not considered to be a hazard.

While ^{137}Cs and ^{90}Sr levels in water and fish of rivers, open lakes and reservoirs are currently low, in some "closed" lakes with no outflowing streams in Belarus, Russia and

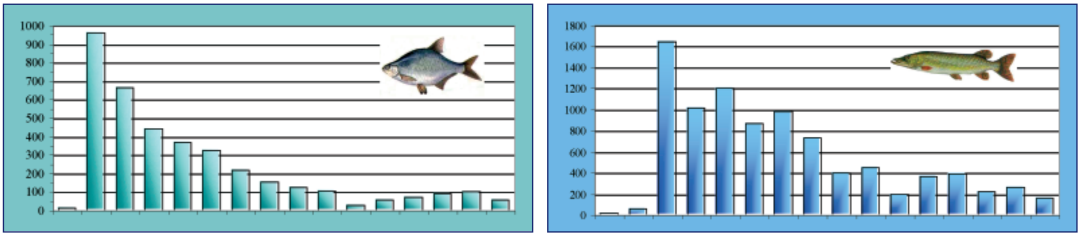


FIG. 6. Averaged ^{137}Cs activity concentrations in non-predatory (Bream, upper histogram) and predatory (Pike, lower histogram) fish from Kyiv reservoir (UHMI 2004).

Ukraine both water and fish will remain contaminated with ^{137}Cs for decades to come. For example, for some people living next to a "closed" Kozhanovskoe Lake in Russia, consumption of fish has dominated their total ^{137}Cs ingestion.

Owing to the large distance of the Black and Baltic Seas from Chernobyl, and the dilution in these systems, activity concentrations in sea water were much lower than in freshwater. The low water radionuclide levels combined with low bioaccumulation of radiocaesium in marine biota has led to ^{137}Cs levels in marine fish that are not of concern.

What environmental countermeasures and remediation have been implemented?

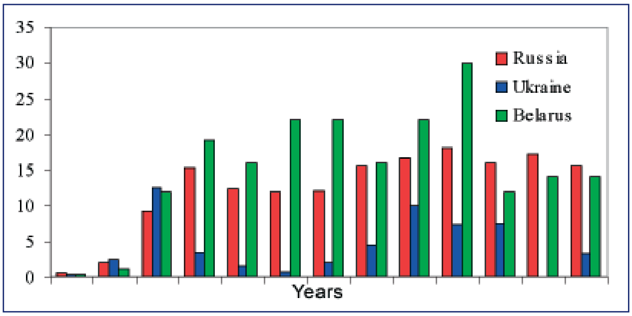
The Soviet and, later, Commonwelth of Independent States (CIS) authorities introduced a wide range of short and long term environmental countermeasures to mitigate the accident's negative consequences. The countermeasures involved huge human, financial and scientific resources.

Decontamination of settlements in contaminated regions of the USSR during the first years after the Chernobyl accident was successful in reducing the external dose when its implementation was preceded by proper remediation assessment. However, the decontamination has produced a disposal problem due to the considerable amount of low-level radioactive waste that was created. Secondary contamination with radionuclides of cleaned up plots from surrounding areas has not been observed.

The most effective agricultural countermeasures in the early phase were exclusion of contaminated pasture grasses from animal diets and rejection of milk based on radiation monitoring data. Feeding animals with "clean" fodder was effectively performed in some affected countries. However, these countermeasures were only partially effective in reducing radioiodine intake via milk because of the lack of timely information about the accident and necessary responses, particularly for private farmers.

The greatest long term problem has been radiocaesium contamination of milk and meat. In the USSR and later in the CIS countries, this has been addressed by the treatment of land used for fodder crops, clean feeding and application of Cs-binders, such as *Prussian blue*, see Fig. 7, to animals that enabled most farming practices to continue in affected areas and resulted in a large dose reduction.

FIG. 7. Changes with time in the use of Prussian blue in the CIS countries (IAEA, 2005).



Application of agricultural countermeasures in the affected CIS countries substantially decreased since the middle of 1990s because of economic problems. In a short time, this resulted in an increase of radionuclide content in plant and animal agricultural products.

In Western Europe, because of the high and prolonged uptake of radiocaesium in the affected extensive systems, a range of countermeasures are still being used for animal products from uplands and forests.

The following forest-related restrictions widely applied in the USSR and later in CIS countries and in Scandinavia have reduced human exposure due to residence in radioactively contaminated forests and use of forest products:

— Restrictions on public and forest worker access as a countermeasure against external exposure;

— Restricted harvesting of food products such as game, berries and mushrooms by the public that contributed to reduction of internal doses. In the CIS countries mushrooms are a staple of many diets and, therefore, this restriction has been particularly important;

— Restricted collection of firewood by the public to prevent exposures in the home and garden when the wood is burned and the ash is disposed of or used as a fertiliser;

— Alteration of hunting practices aiming to avoid consumption of meat with high seasonal levels of radiocaesium.

Numerous countermeasures put in place in the months and years after the accident to protect water systems from transfers of radioactivity from contaminated soils were generally ineffective and expensive. The most effective countermeasure was the early restriction of drinking water and changing to alternative supplies. Restrictions on consumption of freshwater fish have also proved effective in Scandinavia and Germany, though in Belarus, Russia and Ukraine such restrictions may not always have been adhered to.

What were the radiation-induced effects on plants and animals?

Irradiation from radionuclides released from the accident caused numerous acute adverse effects on the plants and animals living in the higher exposure areas, i.e., up to a distance of 20–30 kilometres from the release point. Outside the exclusion zone, no acute radiation-induced effects in plants and animals have been reported.

The response of the natural environment to the accident was a complex interaction between radiation dose and radiosensitivities of the different plants and animals. Both individual and population effects caused by radiation–induced cell death have been observed in biota inside the Exclusion Zone as follows:

— Increased mortality of coniferous plants, soil invertebrates and mammals; and

— Reproductive losses in plants and animals.

No adverse radiation-induced effect has been reported in plants and animals exposed to a cumulative dose of less than 0.3 Gy during the first month after the accident.

Following the natural reduction of exposure levels due to radionuclide decay and migration, biological populations have been recovering from acute radiation effects. As soon as by the next growing season following the accident, population viability of plants and animals had substantially recovered as a result of the combined effects of reproduction and immigration from less affected areas. A few years were needed for recovery from major radiation-induced adverse effects in plants and animals.

Genetic effects of radiation, in both somatic and germ cells, have been observed in plants and animals of the exclusion zone during the first few years after the Chernobyl accident. Both in the exclusion zone, and beyond, different cytogenetic anomalies attributable to radiation continue to be reported from experimental studies performed on plants and animals. Whether the observed cytogenetic anomalies in somatic cells have any detrimental biological significance is not known.

The recovery of affected biota in the exclusion zone has been facilitated by the removal of human activities, e.g., termination of agricultural and industrial activities. As a result, populations of many plants and animals have eventually expanded, and the present environmental conditions have had a positive impact on the biota in the Exclusion Zone. Indeed, the Exclusion Zone has paradoxically become a unique sanctuary for biodiversity, see Fig. 8.

FIG. 8. A white-tailed eagle chick observed recently in the Chernobyl Exclusion Zone. Before 1986, these rare predatory birds have been hardly found in this area (Sergey Gaschak, 2004).

What are the environmental aspects of dismantlement of the Shelter and of radioactive waste management?

The accidental destruction of Chernobyl's Unit 4 reactor generated extensive radioactive contamination and a large amount of radioactive waste in the Unit, at the plant site and in the surrounding area. Construction of the Shelter between May and November 1986, aiming at environmental containment of the damaged reactor, reduced radiation levels on-site and prevented further release of radionuclides off-site.

The Shelter was erected in a short period under conditions of severe radiation exposure to personnel. Measures taken to save construction time and to reduce the high dose rates inside the structure led to imperfections in the Shelter as well as to lack of comprehensive data on the stability of the damaged Unit 4 structures. In addition, structural elements of the Shelter have degraded due to moisture-induced corrosion during the nearly two decades since it was erected. The main potential hazard of the Shelter is a possible collapse of its top structures and release of radioactive dust into the environment.

To avoid the potential collapse of the Shelter, measures are planned to strengthen unstable structures. In addition, a New Safe Confinement (NSC) that should provide more than 100 years service life is planned as a cover over the existing Shelter, see Fig. 9.

The construction of the NSC is expected to allow for the dismantlement of the current Shelter, removal of highly radioactive Fuel Containing Mass (FCM) from Unit 4, and eventual decommissioning of the damaged reactor.

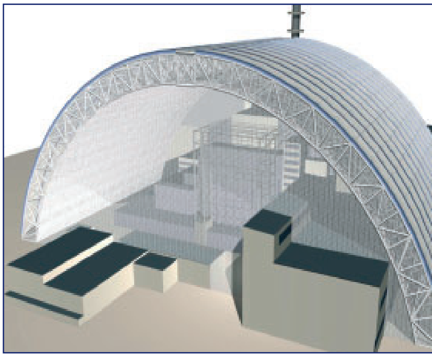


FIG. 9. Planned New Safe Confinement over the destroyed Chernobyl reactor.

In the course of remediation activities both at the Chernobyl nuclear power plant site and in its vicinity, large volumes of radioactive waste were generated and placed in temporary near-surface waste storage and disposal facilities. Trench and landfill facilities were created from 1986 to 1987 in the Exclusion Zone at distances of 0.5 to 15 km from the reactor site with the intention to avoid the spread of dust, reduce the radiation levels, and enable better working conditions at Unit 4 and in its surroundings. These facilities were established without proper design documentation and engineered barriers and do not meet contemporary waste safety requirements.

During the years following the accident large resources were expended to provide a systematic analysis and an acceptable strategy for management of existing radioactive waste. However, to date a broadly accepted strategy for radioactive waste management at the Chernobyl power plant site and the Exclusion Zone, and especially for high-level and long lived waste, has not yet been developed.

More radioactive waste is potentially expected to be generated in the years to come during NSC construction, possible Shelter dismantling, FCM removal and decommissioning of Unit 4. This waste should be properly disposed of.

What is the future of the Chernobyl Exclusion Zone?

The overall plan for the long term development of the Exclusion Zone is to recover the affected areas, redefine the Exclusion Zone, and make the less affected areas available

for use by the public. This will require well defined administrative controls on the nature of activities that may be performed in the resettled areas, restriction of food crops planting and cattle grazing, and use of only clean feed for cattle. Accordingly, these resettled areas are best suited for an industrial use rather than an agricultural or residential area.

The future of the Exclusion Zone for the next hundred years and more is envisaged to be associated with the following activities:

— Construction and operation of the NSC and relevant engineering infrastructure;

— De-fuelling, decommissioning and dismantling of Units 1, 2 and 3 of the nuclear power plant and the Shelter;

— Construction of facilities for processing and management of radioactive waste, in particular a deep geological repository for high-activity and long lived radioactive material;

— Development of natural reserves in the area that remains closed to human habitation; and

— Maintenance of environmental monitoring and research activities.

The Socio-economic Impact of the Chernobyl Nuclear Accident

What was the economic cost of the Chernobyl nuclear disaster?

The Chernobyl nuclear accident, and government policies adopted to cope with its consequences, imposed huge costs on the Soviet Union and three successor countries, Belarus, the Russian Federation and the Ukraine. These costs are impossible to calculate precisely, owing to the non-market conditions prevailing at the time of the disaster and the high inflation and volatile exchange rates of the transition period that followed the break-up of the Soviet Union in 1991. However, the magnitude of the impact is clear from a variety of government estimates from the 1990s, which put the cost of the accident, over two decades, at hundreds of billions of dollars.

The scale of the burden is clear from the wide range of costs incurred, both direct and indirect:

— Direct damage caused by the accident;

— Expenditures related to:

  - Actions to seal off the reactor and mitigate the consequences in the exclusion zone;
  - Resettlement of people and construction of new housing and infrastructure to accommodate them;
  - Social protection and health care provided to the affected population;
  - Research on environment, health and production of clean food;
  - Radiation monitoring of the environment; and
  - Radioecological improvement of settlements and disposal of radioactive waste.

— Indirect losses relating to the opportunity cost of removing agricultural land and forests from use and the closure of agricultural and industrial facilities; and

— Opportunity costs, including the additional costs of energy resulting from the loss of power from the Chernobyl and the cancellation of Belarus's nuclear power programme.

Coping with the impact of the disaster has placed a huge burden on national budgets. In Ukraine, 5–7 percent of government spending each year is still devoted to Chernobyl-related benefits and programmes. In Belarus, government spending on Chernobyl amounted to 22.3 percent of the national budget in 1991, declining gradually to 6.1 percent in 2002. Total spending by Belarus on Chernobyl between 1991 and 2003 was more than US $ 13 billion.

This massive expenditure — of which the lion's share now goes to social benefits for some 7 million "Chernobyl victims," while the share spent on capital investments has sharply declined — has created an unsustainable fiscal burden, particularly in Belarus and Ukraine. Governments face a difficult choice of either reneging on payments or restructuring benefits to target those groups most at risk to radiation hazards and to assist those confronted with poverty (see next page).

What were the main consequences of Chernobyl for the local economy?

The contaminated territories are mostly rural. The main source of income before the accident was agriculture, both in the form of large collective farms (in the Soviet period), which provided wages and many social benefits, and small individual plots, which were cultivated for household consumption and local sale. Industry was mainly low value-added in nature, concentrated in food processing or wood products. This profile has remained largely the same after the accident, though the three countries have taken different approaches to the legacy of collective farms.

The agricultural sector was the area of the economy worst hit by the effects of the accident. A total of 784 320 hectares of agricultural land was removed from service in the three countries, and timber production was halted for a total of 694 200 hectares of forest. Imposing radiological controls severely restricted the market for foodstuffs and other products from the affected areas. “Clean food” production has remained possible in many areas thanks to remediation efforts, but this has entailed higher costs in the form of fertilizers, additives and special cultivation processes.

Even where remediation measures have made farming safe, the stigma of Chernobyl has caused some consumers to reject products from contaminated areas. Food processing, which had been the mainstay of industry in much of the region, has been particularly hard-hit by this “branding” issue. Revenues from agricultural activities have fallen, certain types of production have declined, and some facilities have closed altogether. In Belarus, where some of the best arable land was removed from production, the impact on agriculture has affected the whole economy.

Government policies aimed at protecting the population from radiation exposure (both through resettlement and through limitations on agricultural production) left the region’s economy — particularly the rural economy — in a precarious state. However, it is crucial to note that the region also faced great economic turmoil in the 1990s owing to factors completely unrelated to radiation. The disruption of trade accompanying the collapse of the Soviet Union, the introduction of market mechanisms, prolonged recessionary trends, and Russia’s rouble crisis of 1998 all combined to undercut living standards, heighten unemployment and deepen poverty. Agricultural regions, whether contaminated by radiation or not, were particularly vulnerable to these threats.

Wages tend to be lower and unemployment higher in the contaminated areas than elsewhere. This is because agricultural workers are generally the lowest-paid employees in each country. Employment options outside of agriculture are limited, but, again, the causes are as much a consequence of generic factors as of Chernobyl policies. The proportion of small and medium-sized enterprises (SMEs) is far lower in the affected regions than elsewhere. This is partly because many skilled and educated workers, especially the younger ones, have left the region, and partly because — in all three countries — the general business environment discourages entrepreneurship. Private investment is also low, in part owing to image problems, in part to unfavourable conditions for business nationwide.

The result of these trends is that the contaminated regions face a higher risk of poverty than elsewhere. In seeking solutions to the region's economic malaise, it is important to address the generic issues (improving the business climate, encouraging the development of SMEs and the creation of jobs outside agriculture, and eliminating the barriers to profitable land use and efficient agricultural production) as well as addressing the issues of radioactive contamination.

What impact did Chernobyl and its aftermath have on local communities?

Since the Chernobyl accident, some 350 000 people have been relocated away from the most severely contaminated areas. 116 000 of them were evacuated immediately after the accident, whereas a larger number were resettled several years later, when the benefits of relocation were less evident.

Although resettlement reduced the population's dose of radiation, it was for many a deeply traumatic experience. Even when resettlers were compensated for their losses, offered free houses and given a choice of resettlement location, many retained a deep sense of injustice about the process. Many are unemployed and believe they are without a place in society and have little control over their own lives. Some older resettlers may never adjust. Opinion polls suggest that many resettlers wished to return to their native villages. Paradoxically, people who remained in their villages (and even more so the "self-settlers," those who were evacuated and then returned to their homes despite restrictions) have coped better psychologically with the accident's aftermath than have those who were resettled to less contaminated areas.

Resettlement not only affected the lives of the resettlers, but also those of the residents of the communities into which they were moved. Tensions between new and old residents of resettlement villages have contributed to the newcomers' feelings of ostracism.

Communities in the contaminated areas suffer from a highly distorted demographic structure. As a result of resettlement and voluntary migration, the percentage of elderly individuals in contaminated areas is abnormally high. In some districts, the population of pensioners equals or already exceeds the working-age population. In fact, the more contaminated a region, the older its population. A large proportion of skilled, educated and entrepreneurial people have also left the region, hampering the chances for economic recovery and raising the risk of poverty.

The departure of young people has also had psychological effects. An aging population naturally means that the number of deaths exceeds the number of births, yet this fact has encouraged the belief that the areas concerned were dangerous places to live. Schools, hospitals, agricultural cooperatives, utility companies and many other organisations are short of qualified specialists, even when pay is relatively high, so the delivery of social services is also threatened.

What has been the main impact on individuals?

As noted in the Chernobyl Forum report on Health, "the mental health impact of Chernobyl is the largest public health problem unleashed by the accident to date." Psychological distress arising from the accident and its aftermath has had a profound impact on individual and community behaviour. Populations in the affected areas exhibit strongly negative attitudes in self-assessments of health and well-being and a strong sense of lack of control over their own lives. Associated with these perceptions is an exaggerated sense of the dangers to health of exposure to radiation. The affected populations exhibit a widespread belief that exposed people are in some way condemned to a shorter life expectancy. Such fatalism is also linked to a loss of initiative to solve the problems of sustaining an income and to dependency on assistance from the state.

Anxiety over the effects of radiation on health shows no sign of diminishing. Indeed, it may even be spreading beyond the affected areas into a wide section of the population. Parents may be transferring their anxiety to their children through example and excessively protective care.

Yet while attributing a wide variety of medical complaints to Chernobyl, many residents of the affected areas neglect the role of personal behaviour in maintaining health. This applies not only to radiation risks such as the consumption of mushrooms and berries from contaminated forests, but also to areas where individual behaviour is decisive, such as misuse of alcohol and tobacco.

In this context, it is crucial to note that adult mortality has been rising alarmingly across the former Soviet Union for several decades. Life expectancy has declined precipitously, particularly for men, and in the Russian Federation stood at an average of 65 in 2003 (just 59 years for men). The main causes of death in the Chernobyl-affected region are the same as those nationwide — cardiovascular diseases, injuries and poisonings — rather than any radiation-related illnesses. The most pressing health concerns for the affected areas thus lie in poor diet and lifestyle factors such as alcohol and tobacco use, as well as poverty and limited access to primary health care.

Added to exaggerated or misplaced health fears, a sense of victimization and dependency created by government social protection policies is widespread in the affected areas. The extensive system of Chernobyl-related benefits (see below) has created expectations of long term direct financial support and entitlement to privileges, and has undermined the capacity of the individuals and communities concerned to tackle their own economic and social problems. The dependency culture that has developed over the past two decades is a major barrier to the region's recovery. These factors underscore the importance of measures aimed at giving the individuals and communities concerned control over their own futures — an approach that is both more efficient in use of scarce resources and crucial to mitigating the accident's psychological and social impact.

How have governments responded to the challenges of Chernobyl?

Important features of the policies adopted by the Soviet Union and pursued by the governments of Belarus, Russia and Ukraine can only be properly understood in the context of Soviet conditions and practices and the politics of the transition period. Soviet legislation gave high priority to the protection of the welfare of the citizen but, because of the absence of market based pricing, planners lacked the means to balance costs and benefits effectively. Exchange of information and dissent were limited, while the state possessed very considerable powers of compulsion.

Following the Chernobyl accident, the Soviet government adopted a very cautious policy with regard to the level of radioactive contamination that was considered acceptable for inhabited areas. A large number of people were subject to compulsory or voluntary resettlement. Because of the political environment, the Soviet state was able to embark on resettling several hundred thousand people without serious challenge from the communities concerned.

Rehabilitation actions were undertaken by the Soviet Union, and later by Belarus, Russia and Ukraine, on a hugely ambitious scale. Large investments were made in the construction of housing, schools, and hospitals, and also in physical infrastructure such as roads, water and electricity supply and sewerage.

Chernobyl-related construction, 1986–2000

	Belarus	Russia	Ukraine	Total
Houses and flats	64 836	36 779	28 692	130 307
Schools (number of places)	44 072	18 373	48 847	111 292
Kindergartens (number of places)	18 470	3 850	11 155	33 475
Outpatient health centres (visits/day)	20 922	8 295	9 564	38 781
Hospitals (beds)	4 160	2 669	4 391	11 220

Because of the risk that was believed to be involved in burning locally produced wood and peat, many villages were provided with access to gas supplies for heating and cooking. This involved laying down a total of 8 980 kilometres of gas pipeline in the three countries in the fifteen years following the accident. Large sums were also spent to develop methods to cultivate “clean food”.

Such a massive investment programme proved unsustainable, particularly in market conditions. Funding for Chernobyl programmes has declined steadily over time, leaving many projects half completed and thousands of half-built houses and facilities standing abandoned in resettlement villages. The funding squeeze has also left many promised benefits under-funded.

The system of compensation payments established after the accident reflected a Soviet practice of, in effect, compensating exposure to risk rather than actual injury. The benefits extended included many measures, such as free dental care or preferential admission to university, that had no identifiable relation to the impact of radiation. As was also Soviet practice, benefits were offered to very broad categories of “Chernobyl victims”, defined as people who:

- Fell ill with radiation sickness or became invalids due to the consequences of the accident;
- Took part in clean-up activities on the Chernobyl site and in the evacuation zones in 1986–1987 (the “liquidators”);
- Participated in clean-up activities in 1988–1989;
- Continued to live in areas designated as contaminated; or,
- Were evacuated, or resettled, or left the affected areas on their own initiative.

Some 7 million people are now receiving (or at least entitled to) special allowances, pensions and health care privileges as a result of being categorised as in some way affected by Chernobyl. The benefits confer certain advantages and privileges even to those citizens who had been exposed to low levels of radiation or who continue to live in only mildly contaminated locations, where the level of radiation is similar to natural background levels in some other European countries.

By the late 1990s, Belarusian and Russian legislation provided more than seventy, and Ukrainian legislation more than fifty, different privileges and benefits for Chernobyl victims, depending on factors such as the degree of invalidity and the level of contamination. The system also guaranteed allowances, some of which were paid in cash, while others took the form of, for example, free meals for schoolchildren. In addition, the authorities undertook to finance health holidays in sanatoria and summer camps for invalids, liquidators, people who continued to live in highly contaminated areas, children and adolescents. In Belarus, almost 500 000 people, including 400 000 children, had the right to free holidays in the early 2000s. In Ukraine, the government funded 400 000–500 000 health holiday months per year between 1994 and 2000.

Somewhat counter-intuitively, the number of people claiming Chernobyl-related benefits soared over time, rather than declined. As the economic crisis of the 1990s deepened, registration as a victim of Chernobyl became for many the only means of access to an income and to vital aspects of health provision, including medicines. Corruption played a role. According to Ukrainian figures, the number of people designated as permanently disabled by the Chernobyl accident (and their children) increased from 200 in 1991 to 64 500 in 1997 and 91 219 in 2001. The system has also created perverse incentives, which are clear, for example, in cases of people returning to the affected areas with their families in order to be able to claim a higher level of benefits.

With inflation and increasing budget constraints, however, the value of the payments steadily fell. In many cases, Chernobyl payments became meaningless in terms of their contribution to family incomes, but, given the large number of eligible people, remained a major burden on the state budget. Especially for Belarus and Ukraine, Chernobyl benefits drained resources away from other areas of public spending. By the late 1990s, however, scaling them down, or exploring alternative strategies that would target high-risk groups was politically untenable, even if scarce funds and abuses meant that entitlements were at times distributed unequally.

The enormous scale of the effort currently being made by the three governments means that even small improvements in efficiency could significantly increase the resources available for those in need. Assessing the costs and benefits of particular interventions more rigorously, and targeting resources to those whose health has actually suffered from the catastrophe, should be a high priority. There is a need to sharpen priorities and streamline existing programmes. Benefits that are mainly socio-economic in nature should be folded into a nationwide means-tested social protection programme that targets the truly needy. Such changes, however, will take courage, as reallocating resources is likely to face strong resistance from vested interests. One idea that would both ease the burden on government budgets and encourage self-sufficiency would be to "buy out" benefit entitlements in return for lump-sum start-up finance for small businesses.

Do people living in the affected regions have an accurate sense of the risks they face?

Nearly two decades after the Chernobyl accident, residents of affected areas still lack the information they need to lead healthy, productive lives, according to a range of opinion polls and sociological studies conducted in recent years. Although accurate information is accessible and governments have made many attempts at dissemination, misconceptions and myths about the threat of radiation persist, promoting a paralysing fatalism among residents. This fatalism yields both excessively cautious behaviour (constant anxiety about health) and reckless conduct (consumption of mushrooms, berries and game from areas of high contamination).

These findings were most recently confirmed by three country-specific reports prepared as part of the International Chernobyl Research and Information Network (ICRIN), a UN initiative to provide accurate and credible information to populations affected by the Chernobyl disaster. Surveys and focus group meetings involving thousands of people in each of the three countries in 2003–2004 showed that, despite concerted efforts by governments, scientists, international organizations, and the mass media, people living in the areas affected by the Chernobyl accident express deep confusion and uncertainty about the impact of radiation on their health and surroundings. Awareness is low of what practical steps to take to lead a healthy life in the region.

Overcoming mistrust of information provided on Chernobyl remains a major challenge, owing to the early secrecy with which Soviet authorities treated the accident, the use of conflicting data by different institutions, the unresolved controversies surrounding the impact of low-dose radiation on health, and the often complex scientific language in which information is presented.

Surveys showed that Chernobyl-area residents in all three countries are preoccupied with their own health and that of their children, but concern about low living standards is also extremely pronounced. Indeed, socio-economic concerns were viewed as more important than the level of radiation. Specifically, low household incomes and high unemployment cause uncertainty, see Fig. 10.

What worries you most today?

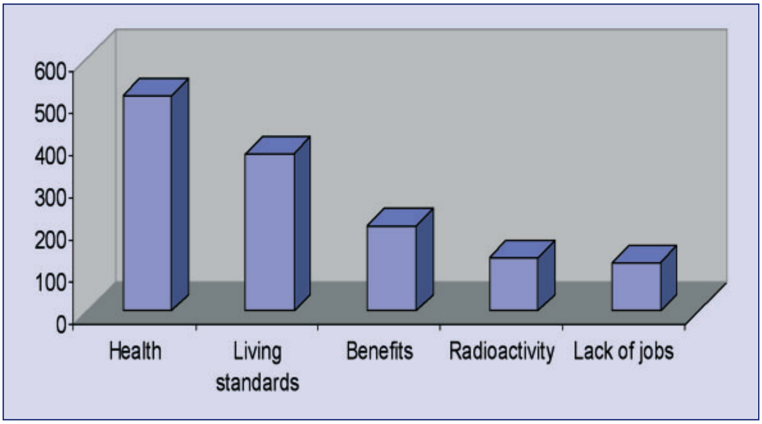


FIG. 10. Data from 2003 Russian survey, 748 respondents, multiple responses allowed.

The ICRIN country studies confirm that Chernobyl-affected populations need unambiguous and comprehensible answers to a range of questions, as well as fresh policies that would focus on promoting the region's economic development. To get the message across, new ways of information delivery and education need to be found. The Chernobyl Forum findings should provide authoritative source material for creative dissemination to the affected populations, helping them both to lead healthier lives and overcome a paralyzing legacy of worry and fear.

What are the current needs of various affected groups?

In order best to address the human needs resulting from the accident, and to optimize use of scarce resources, it is important to understand the true nature of the threat, and number of people actually at risk. Current scientific knowledge suggests that a small but important minority, numbering between 100 000–200 000, is caught in a downward spiral of isolation, poor health and poverty, and needs substantial material assistance to rebuild their lives. This group includes those who continue to live in severely contaminated areas and who are unable to support themselves adequately, unemployed resettlers and those whose health is most directly threatened, including the victims of thyroid cancer. These people are right at the core of the cluster of problems created by Chernobyl. Resources should be focused on resolving their needs and on helping them to take control of their destinies in the circumstances that have resulted from the accident.

A second group, numbering several hundreds of thousands of individuals, consists of those whose lives have been directly and significantly affected by the consequences of the accident but who are already in a position to support themselves. This group includes resettlers who have found employment and many of the former clean-up workers. The priority here should be to help these people to normalise their lives as quickly and as far as is possible. They need to be reintegrated into society as a whole, so that their needs are increasingly addressed through main-stream provision and according to the same criteria as apply to other sections of society.

A third group consists of a much larger number of people, totalling several million in the three countries, whose lives have been influenced by the accident primarily in that they have been labelled as, or perceive themselves as, actual or potential victims of Chernobyl. Here the main need is for full, truthful and accurate information on the effects of the accident based on dependable and internationally recognised research, coupled with access to good quality main-stream provision in health care and social services; and to employment.

The approach of defining the most serious problems and addressing them with special measures, while pursuing an overall policy of promoting a return to normality, should apply to the affected territories as well as to the affected individuals and communities.

Where in the light of the best scientific knowledge it is reasonably possible, measures should be adopted to integrate less severely affected areas back into productive use. This combination of measures — *focusing resources on those most in need, while actively promoting integration with mainstream provision wherever possible* — is not a second best. Within the available budgets it is really the only alternative to the progressive breakdown of the recovery effort, continuing haemorrhaging of scarce resources and continuing distress for the people at the centre of the problem. By fostering a process of healing, these measures will help to address the widespread psychosocial effects of the accident. They will protect the most vulnerable as Chernobyl budgets inevitably decline and will enable the authorities to promote an orderly process of recovery over the coming years.

Recommendations to the governments of Belarus, the Russian Federation and the Ukraine

Introduction

At the Chernobyl Forum meeting in April 2005 where the two reports of the expert groups — "Health", coordinated by the WHO, and "Environment", coordinated by the IAEA — were considered and approved, the Forum participants from Belarus, the Russian Federation and the Ukraine requested the Forum to develop recommendations for the Governments of these three countries on special health care programmes and environmental remediation, including needs for further research, as well as for economic and social policies.

The document was prepared by the Forum Secretariat initially based on the recommendations presented in the Forum's technical reports. In addition, UNDP has contributed recommendations for economic and social policies based largely on the 2002 UN study, *Human Consequences of the Chernobyl Nuclear Accident – A Strategy for Recovery*. The recommendations were circulated among the Forum's participants and eventually accepted by consensus.

This document contains mostly generic advice for the Governments of the three affected countries; more detailed recommendations can be found in the respective technical reports. With regard to radiation protection of the public and the environment, the recommendations are based on current concepts of the International Commission on Radiological Protection (ICRP) and international safety standards developed by the IAEA.

Health Care and Research: Recommendations

Health care programmes and medical monitoring

Medical care and annual examinations of the workers who recovered from Acute Radiation Syndrome (ARS) and other highly exposed emergency workers should continue. This should include periodic examination for cardiovascular disease.

Current follow-up programmes for those persons with whole body exposures of less than 1 Gy should be reconsidered relative to necessity and cost effectiveness. From previous knowledge, these follow-up programmes are unlikely to be cost effective or beneficial to patients. Resources used for extensive examinations by teams of experts and blood and urine examination on an annual basis might more profitably be directed towards more programmes to reduce infant mortality, reduce alcohol and tobacco use, to detect cardiovascular disease and to improve the mental health status of the affected population.

The following specific health related actions are recommended:

— Populations known to be particularly sensitive subgroups (e.g. children exposed to significant amounts of radioiodine) that are at much higher risk than the general population should be considered for screening.

— Screening for thyroid cancer of children and adolescents, who resided in 1986 in the areas with radioactive fallout, should continue, but should be evaluated for cost/benefit. This is important because as the population ages, many additional benign lesions will be found and there is a risk from unnecessary invasive procedures.

— For health planning purposes, continuous estimation of the predicted number of cases of thyroid cancer expected to occur in exposed populations should be based on updated estimates of risk in those populations.

— High quality cancer registries should continue to be supported. They will be useful not only for epidemiological studies but also for public health purposes, e.g., providing reliable information to help guide the allocation of public health resources.

— Incidence rates for childhood leukaemia in populations exposed to Chernobyl radiation should continue to be monitored to detect increases that may still occur.

— Continued eye follow-up studies of the Chernobyl populations, will allow greater predictive capability of risk of radiation cataract onset and more importantly provide the data necessary to assess the likelihood of a resulting visual dysfunction. Annual monitoring for radiation cataract development may be recommended in case of occupational exposure to radiation.

— The local registers on reproductive health outcomes should be continued and improved as a public health measure but are unlikely to provide useful scientific information on radiation effects. However they may provide reassurance to the local population.

— Renewed efforts at risk communication should be undertaken, providing the public and key professionals with accurate information about the physical and mental health consequences of the disaster.

— Any medical follow-up studies should be conducted with an estimation of individual absorbed radiation dose to the tissue of interest and appropriate control groups and assessment of confounding factors.

Future research and follow-up studies

Registries of exposed persons should continue as well as studies of morbidity and mortality. These are typically for documentation or research purposes and usually will not be of direct medical benefit to the individual.

Limited research studies should be continued on selected populations when a new scientific technique or findings are discovered that may play a role in ameliorating potential radiation effects.

Because elevated radiation-induced morbidity and mortality from solid cancers of both emergency workers and populations of areas contaminated with radionuclides still might be expected during decades to come, this subject requires more research.

Presently, it is not possible to exclude an excess risk of thyroid cancer in persons exposed to Chernobyl radiation as adults. Carefully designed and appropriately analysed studies should be conducted to provide more information on ^{131}I related risks following adult exposure.

Incidence of non-thyroid solid cancers in both the general population and cohorts of liquidators should continue to be monitored through the existing cancer registries and other specialized registries. Efforts to evaluate the quality of those registries and to reduce any deficiencies should be given high priority.

Further work on the evaluation of uncertainties in thyroid dose estimates is strongly encouraged. This should lead to the determination of the parameters that give rise to the highest uncertainties and to research aimed at reducing those uncertainties. Cooperation and exchange of information among the dosimetrists from Belarus, Russia and Ukraine working in that area are strongly encouraged.

A validation study is needed in the three affected countries on the role of radiation in the induction of cardiovascular diseases in emergency workers, using an appropriate control group, adequate dosimetry and common standardized clinical and epidemiological strategies and protocols.

There should be continued study of immune effects after high-absorbed doses (particularly on the survivors of the acute radiation syndrome). Studies of immune function in populations with less than several tens of mGy are unlikely to yield significant information.

Further information

More specific recommendations on Chernobyl-related health research can be found in the technical report of the Chernobyl Forum entitled "Health Effects of the Chernobyl Accident and Special Health Care Programmes" and in its executive summary.

Environmental Monitoring, Remediation and Research: Recommendations

Environmental monitoring and research

Various ecosystems considered in the present report have been intensively monitored and studied during the years after Chernobyl and environmental transfer and bioaccumulation of the most important long term contaminants, ^{137}Cs and ^{90}Sr are now generally well understood. There is therefore little need for major new research programmes on radioactivity; but there is a requirement for continued but more limited targeted monitoring of the environments, and for further research in some specific areas, as detailed in the Technical Report.

Long term monitoring of radionuclides (especially, ^{137}Cs and ^{90}Sr) in various environmental compartments is required to meet the following general practical and scientific needs:

Practical:

— To assess current and predict future levels of human exposure and contamination of foods to assess the need for remedial actions and long term countermeasures;

— To inform the general public in affected areas about the persistence of radioactive contamination in food products and its seasonal and annual variability in natural food products gathered by themselves (such as mushrooms, game, freshwater fish from closed lakes, berries etc) as well as give dietary advice and inform about ways to prepare food to reduce radionuclide intake by humans.

— To inform the general public in affected areas about changing radiological conditions to relieve public concerns.

Scientific:

— To determine parameters of long term transfer of radionuclides in various ecosystems and different natural conditions to improve predictive models both for the Chernobyl-affected areas and for potential future radioactive releases;

— To determine mechanisms of radionuclide behaviour in less studied ecosystems (e.g., role of fungi in the forest) to clarify the persistence of radionuclides and explore remediation possibilities with special attention to processes important in contributing to human and biota doses.

As activity concentrations in environmental compartments are now in quasi-equilibrium and change slowly, the number and frequency of sampling and measurements performed for monitoring and research programmes can be substantially reduced compared with the early years after the Chernobyl accident.

As current human exposure levels caused by the Chernobyl fallout are generally well known and they change slowly, large-scale monitoring of foodstuffs, whole-body counting of individuals, and provision of dosimeters to members of the general population are no longer necessary. However, individual measurements should be still used for critical groups in areas of high contamination and/or high transfer of radiocaesium.

To further develop the system of environmental protection against radiation, the long term impact of radiation on plant and animal populations should be further investigated in the highly contaminated Chernobyl exclusion zone; this is a globally unique area for radioecological and radiobiological research in an otherwise natural setting. Such studies are, except for very small-scale experiments, not possible or difficult to perform elsewhere.

Remediation and countermeasures

A wide range of different effective long term remediation measures are available for application in the areas contaminated with radionuclides but their use should be radiologically justified and optimized. In optimizing countermeasures, social and economic factors should be taken into account, along with formal cost–benefit analysis, so that the use of the countermeasures is acceptable to the public.

The general public, along with the authorities, should be particularly informed about existing radiation risk factors and methods to reduce them in the long term via remediation and regular use of countermeasures, and involved in discussion and decision making.

Particular attention must be given to the production on private farms in several hundred settlements and about 50 intensive farms in Belarus, Russia and Ukraine where radionuclide concentrations in milk still exceed national action levels.

In the long term after the Chernobyl accident, remediation measures and regular countermeasures remain efficient and justified mainly in agricultural areas with poor (sandy and peaty) soils where there is a high radiocaesium transfer from soil to plants.

Among long term remediation measures, radical improvement of pastures and grasslands as well as draining of wet peaty areas is very effective. The most efficient regular agricultural countermeasures are pre-slaughter clean feeding of animals accompanied with *in vivo* monitoring, application of Prussian Blue to cattle and enhanced application of mineral fertilisers in plant breeding.

There are still agricultural areas in the three countries which are taken out of use. However this land can be safety used after appropriate remediation, for which technologies are available, but at the moment legal economic and social constraint may make this difficult. It is desirable to identify sustainable ways to make use of the most affected areas that reflect the radiation hazard, but also revive the economic potential for the benefit of the community.

Technologically based forest countermeasures, such as the use of machinery and/or chemical treatments to alter the distribution or transfer of radiocaesium in the forest, will not be practicable on a large scale.

Restricting harvesting of wild food products such as game, berries, mushrooms and fish from 'closed lakes' by the public still may be needed in areas where their activity concentrations exceed national action levels.

Advice on diet aiming to reduce consumption of highly contaminated wild food products and on simple cooking procedures which remove radiocaesium are still important countermeasures aimed at reducing internal exposure.

It is unlikely that any future countermeasures to protect surface waters will be justifiable in terms of economic cost per unit of dose reduction. It is expected that restrictions on consumption of fish will remain, in a few cases (such as closed lakes), for several more decades. Future efforts in this area should be focused on public information since there are still significant public misconceptions concerning health risks due to contaminated waters and fish.

There is nothing that can be done to remedy the radiological conditions for plants and animals residing in the exclusion zone of the Chernobyl NPP that would not have an adverse impact to plants and animals.

An important issue that requires more sociological research is the perception by the public of the introduction, performance and withdrawal of countermeasures after an emergency as well as development of social measures aiming at involvement of the public in these processes at all stages beginning with the decision making.

There is still substantial diversity in international and national radiological criteria and safety standards applicable to remediation of areas affected by environmental contamination with radionuclides. Experience with protection of the public after the Chernobyl accident has clearly shown the need for further international harmonization of appropriate radiological criteria and safety standards.

Environmental aspects of the Shelter dismantlement and radioactive waste management

Because individual safety and environmental assessments have been performed for individual facilities at and around the Chernobyl NPP, a comprehensive safety and environmental impact assessment should be performed according to the international standards and recommendations that encompasses all activities inside the entire Exclusion Zone.

During the preparation and construction of the New Safe Containment (NSC) and soil removal, it is important to maintain and improve environmental monitoring strategies, methods, equipment and staff qualification needed for adequate monitoring of the conditions at the Chernobyl NPP site and the Exclusion Zone.

Development of an integrated radioactive waste management programme for the Shelter, the Chernobyl NPP site and the Exclusion Zone is needed to ensure application of consistent management approaches, and sufficient facility capacity for all waste types. Specific emphasis needs to be paid to the characterisation and classification of waste (in particular waste containing transuranic elements) from all the remediation and decommissioning activities, as well as the establishment of sufficient infrastructure for safe long term management of long lived and high level waste at the Chernobyl NPP site and in the Exclusion Zone.

A coherent and comprehensive strategy for rehabilitation of the Exclusion Zone is needed with particular focus on improving safety of the existing waste storage and disposal facilities. This will require development of a prioritization method for remediation of the sites, based on safety assessment results, aimed at determining at which sites waste will be retrieved and disposed, and at which sites waste will be allowed to decay in situ.

The overall plan for the long term development of the Exclusion Zone is to recover the affected areas, redefine the Exclusion Zone, and make the non-affected areas available for resettlement by the public. This will require well-defined administrative controls as to the nature of activities that may be performed in the resettled areas, prohibition of food crops and cattle grazing and use of only clean feed for cattle. Accordingly, these resettled areas are best suited for an industrial site rather than a residential area.

Further information

More specific recommendations on Chernobyl-related environmental remediation, monitoring and research issues can be found in the technical report of the Chernobyl Forum entitled “Environmental Consequences of the Chernobyl Accident and Their Remediation: Twenty Years of Experience” and in its executive summary.

Economic and Social Policy: Recommendations

What is to be done?

Current scientific knowledge about the impact of the disaster suggests that five general principles should underlie any approach to tackling the consequences of the accident:

— Chernobyl-related needs should be addressed in the framework of a holistic view of the needs of the individuals and communities concerned and, increasingly, of the needs of society as a whole;

— Moving away from a dependency culture, the aim must be to help individuals to take control of their own lives and communities to take control of their own futures;

— Efficient use of resources means focusing on the most affected people and communities. The response must take into account the limited budgetary resources at government disposal;

— The new approach should seek changes that are sustainable and long term, and based on a developmental approach;

— The international effort can only be effective if it supports, amplifies and acts as a lever for change in the far larger efforts made by local and national government agencies and the voluntary sector in the three countries.

Specific recommendations

Find new ways to inform the public

Study after study — most recently the three information needs assessments conducted in Belarus, the Russian Federation, and Ukraine through the International Chernobyl Research and Information Network (ICRIN) — have confirmed that efforts to disseminate relevant information to the affected populations fallen short of their aims. Accurate information on living in conditions of low-dose radiation is available, yet it is either not reaching some people, or people are unable to digest it or act upon it.

Innovative ways need to be developed to increase knowledge about how to live safely in environments that have suffered radioactive contamination. These need to address the problems of credibility and comprehensibility that have hampered past efforts. Information provision targeted to specific audiences is needed, as well as trusted community sources.

Any new information strategy should embrace a comprehensive approach to promoting healthy lifestyles, and not simply focus on radiation hazards. Health education aiming at reducing internal and external radiation should be just one part of health promotion policies and interventions that aim at reducing the main causes of disease and rising mortality in the three countries.

Focus attention on highly contaminated areas

Government programmes need to be differentiated depending on level of contamination, as problems created by radiation are different among zones. Zones with mild radiation levels can be made fit for adequate and even prosperous living with limited, cost effective measures to reduce radiation exposure. The far smaller areas with higher levels of contamination require a different strategy focused on greater monitoring, provision of health and social services, and other assistance.

Streamline and refocus government programmes on Chernobyl

In order to meet the objectives of reducing the population's exposure to radiation and providing support to those who have been directly affected by the accident, current Chernobyl programmes need to be refocused in order to meet these objectives in a cost effective manner. Programs should shift from those that create a victim and dependency mentality to those that support opportunity, promote local initiatives, involve the people and spur their confidence in shaping their destinies.

Adjustments to Chernobyl programmes should be guided by the following criteria:

— Aligning programmes with new objectives;

— Preventing the creation of perverse incentives; and

— Matching the mandates with available resources.

These criteria suggest that certain programmes should be strengthened and expanded (e.g., supporting the production of clean food, monitoring and certification), whereas others should be revamped to target those genuinely in need (e.g., cash benefits linked to place of residence, health recuperation, free meals for children, free medicine, mandatory mass screening).

— **Improve benefits targeting.** Many entitlements are not related to the health impact of radiation, but are mainly socio-economic in nature and correlated with residence rather than with any demonstrated need. These should be replaced with targeted programs for the needy. Chernobyl-related benefits and privileges should be folded into a mainstream social assistance programme that is targeted and means-tested. The definition of those who qualify as "Chernobyl victims" should be made more stringent and its application more effective, so that only those who indeed suffered from the accident benefit from this assistance.

— **Consider eliminating benefits for citizens living in areas with mild contamination.** Enormous sums are currently spent on benefits that make little significant difference to individual households yet pose a huge burden on national budgets — or are not paid at all owing to revenue shortfalls. Moreover, correlating benefits with area of residence alone is unsound public policy, particularly where radiation levels are as low as natural background levels in other parts of Europe. Inhabitants should not be eligible for most benefits unless a causal connection between the accident and individual ill health can be demonstrated. Those who need state assistance on poverty grounds should be covered by a nationwide targeted and means-tested system of social assistance.

— **Improve primary health care, including psychological support.** Strengthening of primary health care services in contaminated areas should receive priority. This should include promotion of healthy lifestyles; improvement in access and quality of reproductive health care, especially obstetric health care in the most contaminated areas; and provisions of psychological support and diagnosis and treatment of mental diseases, especially depression. At the same time, free prescription medicine and dental services should be eliminated, except where some causal connection between the accident and health status can be demonstrated.

— **Rethink health recuperation programmes.** The provision of sanatoria and recuperation is not cost effective, and such holidays offer little that is of direct health benefit to those exposed to low-dose radiation. In addition, they carry a strong suggestion that the affected areas are somehow "poisonous" and thus unsuitable for human habitation. Moreover, access to the programmes is not always equitable. Funding could be better used in primary health care provision and promoting healthy lifestyles. International charities offering health holidays should also be asked to rethink their efforts. While recognising the enormous good will and effort that has gone into programmes providing children with "health holidays" abroad, and also the popularity of such holidays, international charities should be encouraged to refocus their energies on measures that promote better health outcomes in affected communities — or to give their activities a broader label than that of Chernobyl.

— **Encourage safe food production.** Continued efforts are needed to develop and promote agricultural products that can be produced safely where radionuclides are present in the soil. Know-how is available, but some countermeasures are currently not being applied due to the lack of funds. Little is being done to ensure the production of clean food on private plots, and thus to address the issue of food being produced for personal consumption or for sale on village markets. But cost–benefit analysis is essential in propagating mitigation measures, as the costs of producing "clean food" may exceed any reasonable market value.

Adopt a new approach to economic development of the affected regions

— **Put economic development aiming to make the affected communities economically and socially viable** in the medium and long term at the centre of strategies to address the effects of Chernobyl. This should be done in such a way as to give the individuals and communities concerned **control over their own futures**, which is both efficient in terms of resources and crucial in addressing the psychological and social effects of the accident. Understand that very large resources are needed to promote the economic recovery in these communities, but also that achieving **economic self-sufficiency and community self-reliance** will free up large national resources, which are at present tied up in subsidies and special Chernobyl-related assistance.

— **Improve the business climate, encourage investment and support private sector development.** At the national level, sound finances and the creation of an open competitive market economy and an investment friendly business environment are preconditions for sustained recovery in the affected areas. Appropriate national policies need to be supplemented by a proactive approach to stimulating economic development at the regional and local levels. Economic incentives, such as special zones, should be used only in tandem with improvement in the business environment, as the use of tax and other incentives to attract entrepreneurial and skilled people to the region may not work in an unfriendly business environment or because badly designed instruments may lead to perverse incentives.

— **Support initiatives to promote inward investment, both domestic and international** at the regional level, to promote employment and create a positive image for the areas concerned. The international community can play an important part in this effort by assisting in **transferring experience** from successful initiatives in other parts of the world that have been blighted by economic restructuring, high levels of unemployment and environmental contamination. Build on experience of the **local economic development agencies** already functioning in the region to build a network of intermediary organisations that are sensitive to local conditions and can act as an interface with national and international development bodies and donors.

— **Encourage the creation and growth of small and medium-size enterprises** in the affected areas and in the adjacent towns and cities using the whole range of business support techniques that have been tried and tested in other parts of the world. Because of the nature of the local economies concerned, particular efforts are needed to promote **indigenous agricultural and food processing businesses** by supporting the growth of existing enterprises (whatever their ownership status), and through new ventures.

— **Adapt examples of good practice** in the three countries and abroad, including community based solutions such as **credit unions and producer and consumer cooperatives,** to the special circumstances that apply in the affected areas. An appropriate legal and organisational framework should be developed to ensure that such businesses get the support that they need.

— **Give high priority to supporting very small-scale business development** as the local level, including village level enterprise clusters to boost the incomes of the poorest households. Such initiatives must draw on the growing body of international experience in this area and be sensitive to the very special problems affecting communities that largely depend on food production in areas suffering from radioactive contamination.

— **Promote the rebuilding of community structures** to replace those that were lost in the process of evacuation and as a result of the break up of the Soviet Union. Initiatives specifically designed to strengthen social interactions and promote **community and economic leadership** in towns and villages are needed to underpin sustainable recovery.

— **Explore the possibilities for promoting specialised ecological tourism** and for maximising the contribution that these areas can make to the **preservation of international biodiversity.** Little attempt had been made to exploit the reduction of human disturbance to the ecosystems and cultural landscape in a positive way and the current national plans for biodiversity protection and cultural preservation hardly refer to this potential. The territories could be used to fulfil the three countries' **international obligations on the protection of biodiversity**.

Further information

More detailed policy recommendations on improving socio-economic conditions and reviving community life in Chernobyl-affected areas can be found in the UN publication, *Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery* (2002), and the World Bank's Belarus: *Chernobyl Review* (2002).

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