Health effects of the Chernobyl accident: an overview

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Background

On 26 April 1986, explosions at reactor number four of the nuclear power plant at Chernobyl in Ukraine, a Republic of the former Soviet Union at that time, led to huge releases of radioactive materials into the atmosphere. These materials were deposited mainly over countries in Europe, but especially over large areas of Belarus, the Russian Federation and Ukraine.

An estimated 350 000 clean-up workers or "liquidators" from the army, power plant staff, local police and fire services were initially involved in containing and cleaning up the radioactive debris during 1986-1987. About 240 000 liquidators received the highest radiation doses while conducting major mitigation activities within the 30 km zone around the reactor. Later, the number of registered liquidators rose to 600 000, although only a small fraction of these were exposed to high levels of radiation.

In the spring and summer of 1986, 116 000 people were evacuated from the area surrounding the Chernobyl reactor to non-contaminated areas. Another 230 000 people were relocated in subsequent years.

Currently about five million people live in areas of Belarus, the Russian Federation and Ukraine with levels of radioactive caesium deposition more than 37 kBq/m2 [1]. Among them, about 270 000 people continue to live in areas classified by Soviet authorities as strictly controlled zones (SCZs), where radioactive caesium contamination exceeds 555 kBq/m2.

Evacuation and relocation proved a deeply traumatic experience to many people because of the disruption to social networks and having no possibility to return to their homes. For many there was a social stigma associated with being an "exposed person".

In addition to the lack of reliable information provided to people affected in the first few years after the accident, there was widespread mistrust of official information and the false attribution of most health problems to radiation exposure from Chernobyl.

This fact sheet gives an overview of the health effects of the Chernobyl accident that can be established from high quality scientific studies. For people most affected by the accident, provision of sound, accurate information should assist with their healing process.

WHO health effects review

Within the UN Chernobyl Forum initiative the World Health Organization (WHO) conducted a series of expert meetings from 2003 to 2005 to review all scientific evidence on health effects associated with the accident. The WHO Expert Group used as a basis the 2000 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), updated with critical reviews of published literature and information provided by the governments of the three affected countries. The Expert Group was composed of many scientists who had conducted studies in the three affected countries as well as experts world wide. Special health care programmes, established to treat people in the three countries which were most affected by the accident, were also considered. This resulted in a WHO report on "Health Effects of the Chernobyl Accident and Special Health Care Programmes" (see www.who.int/ionizing_radiation).

The WHO Expert Group placed particular emphasis on scientific quality, using information mainly in peer-reviewed journals, so that valid conclusions could be drawn. In addition, comparisons were made with the results from studies of people involved in previous high radiation-exposure situations, such as the atomic bomb survivors in Japan.

Radiation exposure

Ionizing radiation exposure is measured as "absorbed dose" in gray (Gy). The "effective dose" measured in sievert (Sv) takes account of the amount of ionizing radiation energy absorbed, the type of radiation and the susceptibility of various organs and tissues to radiation damage. For most exposures from the Chernobyl accident, absorbed doses are similar to effective doses (i.e. 1Gy is approximately equal to 1 Sv).

As human beings we are continually exposed to ionizing radiation from many natural sources, such as cosmic rays, and naturally occurring radioactive materials in all the foods we eat, fluids we drink and air we breath. This is called natural background radiation.

UNSCEAR reports that the average natural background radiation dose to human beings worldwide is about 2.4 mSv[2] each year, but this varies typically over the range 1-10 mSv. However, for a limited number of people living in known high background radiation areas of the world, doses can exceed 20 mSv per year. There is no evidence to indicate this poses a health risk.

For most people more than half of their natural background radiation dose comes from radon, a radioactive gas that can accumulate in homes, schools and workplaces. When inhaled, the radiation exposure from radon may lead to lung cancer. Radiation doses to humans may be characterized as low-level if they are comparable to natural background levels.

Doses received from the Chernobyl accident

Below are the total average effective doses accumulated over 20 years by the highest Chernobyl exposed populations. These can be compared with the average doses people normally receive from natural background over 20 years. Doses from typical medical procedures are also given for comparison purposes.

Population (years exposed)	Number	Average total in 20 years (mSv)[1]
Liquidators (1986–1987) (high exposed)	240 000	>100
Evacuees (1986)	116 000	>33
Residents SCZs (>555 kBq/m2)(1986–2005)	270 000	>50
Residents low contam. (37 kBq/m2) (1986–2005)	5 000 000	10–20

Population (years exposed)	Number	Average total in 20 years (mSv)[1]
Natural background	2.4 mSv/year (typical range 1–10, max >20)	48
Approximate typical doses from medical x-ray exposures per procedure:		
Whole body CT scan	12 mSv	
Mammogram	0.13 mSv	
Chest x-ray	0.08 mSv	

[1] These doses are additional to those from natural background radiation.

While the effective doses of most of the residents of the contaminated areas are low, for many people, doses to the thyroid gland were large from ingestion of milk contaminated with radioactive iodine. Individual thyroid doses ranged from a few tens of mGy to several tens of Gy.

Apart from the people exposed to high levels of radioactive iodine mentioned above, only those liquidators who worked around the stricken reactor in the first two years after the accident (240 000), the evacuees (116 000), some of whom received doses well in excess of 100 mSv, and the residents of the highly contaminated SCZs (270 000), received doses significantly above typical natural background levels. Current residents of the low contaminated areas (37 kBq/m2) still receive small doses above natural background levels, but these are well within the typical range of background doses received world-wide. For comparison, the high radiation dose a patient typically receives from one whole body computer tomography (CT) scan is approximately equivalent to the total dose accumulated in 20 years by the residents of the low contaminated areas following the Chernobyl accident.

Thyroid cancer

A large increase in the incidence of thyroid cancer has occurred among people who were young children and adolescents at the time of the accident and lived in the most contaminated areas of Belarus, the Russian Federation and Ukraine. This was due to the high levels of radioactive iodine released from the Chernobyl reactor in the early days after the accident. Radioactive iodine was deposited in pastures eaten by cows who then concentrated it in their milk which was subsequently drunk by children. This was further exacerbated by a general iodine deficiency in the local diet causing more of the radioactive iodine to be accumulated in the thyroid. Since radioactive iodine is short lived, if people had stopped giving locally supplied contaminated milk to children for a few months following the accident, it is likely that most of the increase in radiation-induced thyroid cancer would not have resulted.

In Belarus, the Russian Federation and Ukraine nearly 5 000 cases of thyroid cancer have now been diagnosed to date among children who were aged up to 18 years at the time of the accident. While a large number of these cancers resulted from radiation following the accident, intense medical monitoring for thyroid disease among the affected population has also resulted in the detection of thyroid cancers at a sub-clinical level, and so contributed to the overall increase in thyroid cancer numbers. Fortunately, even in children with advanced tumours, treatment has been highly effective and the general prognosis for young patients is good. However, they will need to take drugs for the rest of their lives to replace the loss of thyroid function. Further, there needs to be more study to evaluate the prognosis for children, especially those with distant metastases. It is expected that the increased incidence of thyroid cancer from Chernobyl will continue for many years, although the long-term magnitude of the risk is difficult to quantify.

Leukaemia and non-thyroid solid cancer

Ionizing radiation is a known cause of certain types of leukaemia (a malignancy of blood cells). An elevated risk of leukaemia was first found among the survivors of the atomic bombings in Japan some two to five years after exposure. Recent investigations suggest a doubling of the incidence of leukaemia among the most highly exposed Chernobyl liquidators. No such increase has been clearly demonstrated among children or adults resident in any of the contaminated areas. From the experience of the Japanese bomb survivors it is possible that a large proportion of the leukaemia cases that could be linked to Chernobyl have already occurred, now that 20 years have passed since the accident. However, further studies are needed to clarify this.

While scientists have conducted studies to determine whether cancers in many other organs may have been caused by radiation, reviews by the WHO Expert Group revealed no evidence of increased cancer risks, apart from thyroid cancer, that can clearly be attributed to radiation from Chernobyl. Aside from the recent finding on leukaemia risk among Chernobyl liquidators, reports indicate a small increase in the incidence of pre-menopausal breast cancer in the most contaminated areas, which appear to be related to radiation dose. Both of these findings, however, need confirmation in well-designed epidemiological studies. The absence of demonstrated increases in cancer risk – apart from thyroid cancer – is not proof that no increase has occurred. Based on the experience of atomic bomb survivors, a small increase in the risk of cancer is expected, even at the low to moderate doses received. Such an increase, however, is expected to be difficult to identify.

Mortality

According to UNSCEAR (2000), 134 liquidators received radiation doses high enough to be diagnosed with acute radiation sickness (ARS). Among them, 28 persons died in 1986 due to ARS. Other liquidators have since died but their deaths could not necessarily be attributed to radiation exposure. An increased number of cancer deaths can be expected during the lifetime of persons exposed to radiation from the accident. Since it is currently impossible to determine which individual cancers were caused by radiation, the number of such deaths can only be estimated statistically using information and projections from the studies of atomic bomb survivors and other highly exposed populations. It should be noted that the atomic bomb survivors received high radiation doses in a short time period, while Chernobyl caused low doses over a long time. This and other factors, such as trying to estimate doses people received some time after the accident, as well as differences in lifestyle and nutrition, cause very large uncertainties when making projections about future cancer deaths. In addition, a significant non-radiation related reduction in the average lifespan in the three countries over the past 15 years caused by overuse of alcohol and tobacco, and reduced health care, have significantly increased the difficulties in detecting any effect of radiation on cancer mortality. Although there is controversy about the magnitude of the cancer risk from exposure to low doses of radiation, the US National Academy of Sciences BEIR VII Committee, published in 2006, a comprehensive review of the scientific evidence, and concluded that the risk seems to continue in a linear fashion at lower doses without a threshold (this is called the “linear no-threshold” or LNT model). However, there are uncertainties concerning the magnitude of the effect, particularly at doses much lower than about 100 mSv.

The Expert Group concluded that there may be up to 4 000 additional cancer deaths among the three highest exposed groups over their lifetime (240 000 liquidators; 116 000 evacuees and the 270 000 residents of the SCZs). Since more than 120 000 people in these three groups may eventually die of cancer, the additional cancer deaths from radiation exposure correspond to 3-4% above the normal incidence of cancers from all causes.

Projections concerning cancer deaths among the five million residents of areas with radioactive caesium deposition of 37 kBq/m2 in Belarus, the Russian Federation and Ukraine are much less certain because they are exposed to doses slightly above natural background radiation levels. Predictions, generally based on the LNT model, suggest that up to 5 000 additional cancer deaths may occur in this population from radiation exposure, or about 0.6% of the cancer deaths expected in this population due to other causes. Again, these numbers only provide an indication of the likely impact of the accident because of the important uncertainties listed above.

Chernobyl may also cause cancers in Europe outside Belarus, the Russian Federation and Ukraine. However, according to UNSCEAR, the average dose to these populations is much lower and so the relative increase in cancer deaths is expected to be much smaller. Predicted estimates are very uncertain and it is very unlikely that any increase in these countries will be detectable using national cancer statistics .[3]

Cataracts

The lens of the eye is very sensitive to ionizing radiation and cataracts are known to result from effective doses of about 2 Sv. The production of cataracts is directly related to the dose. The higher the dose the faster the cataract appears.

Chernobyl cataract studies suggest that radiation opacities may occur from doses as low as 250 mSv. Recent studies among other populations exposed to ionizing radiation (e.g. atomic bomb survivors, astronauts, patients who received CT-scans to the head) support this finding.

Cardiovascular disease

A large Russian study among emergency workers has suggested an increased risk of death from cardiovascular disease in highly exposed individuals. While this finding needs further study with longer follow-up times, it is consistent with other studies, for example, on radiotherapy patients, who received considerably higher doses to the heart.

Mental health and psychological effects

The Chernobyl accident led to extensive relocation of people, loss of economic stability, and long-term threats to health in current and possibly future generations. Widespread feelings of worry and confusion, as well as a lack of physical and emotional well-being were commonplace. The dissolution of the Soviet Union soon after the Chernobyl accident, and the resultant instability in health care, added further to these reactions. High levels of stress, anxiety and medically unexplained physical symptoms continue to be reported among those affected by the accident.

The accident has had a serious impact on mental health and well-being in the general population, mainly at a sub-clinical level that has not generally resulted in medically diagnosed disorders. Designation of the affected population as “victims” rather than “survivors” has led to feelings of helplessness and lack of control over their future. This has resulted in excessive health concerns or reckless behaviour, such as the overuse of alcohol and tobacco, or the consumption of mushrooms, berries and game from areas still designated as having high levels of radioactive caesium.

Reproductive and hereditary effects and children's health

Given the low radiation doses received by most people exposed to the Chernobyl accident, no effects on fertility, numbers of stillbirths, adverse pregnancy outcomes or delivery complications have been demonstrated nor are there expected to be any. A modest but steady increase in reported congenital malformations in both contaminated and uncontaminated areas of Belarus appears related to improved reporting and not to radiation exposure.

WHO's role

The Expert Group report is a milestone in WHO´s efforts to assess and mitigate the health impact of the Chernobyl accident. WHO will actively promote the research and practical recommendations given in this report. In addition WHO will ensure that the people most affected by the Chernobyl accident will be provided with scientifically factual information that will allow them to make better-informed decisions about their health and future .

Further information

WHO Expert Group report "Health Effects of the Chernobyl Accident and Special Health Care Programmes: Report of the UN Chernobyl Forum Health Expert Group, Editors Burton Bennett, Michael Repacholi and Zhanat Carr, World Health Organization, Geneva, 2006. Also available at: www.who.int/ionizing_radiation.

UNSCEAR (2000) United Nations Scientific Committee on the Effects of Atomic Radiation. 2000 Report to the General Assembly, with Scientific Annexes. Volume II: Effects. New York. United Nations. Also available at: http://www.unscear.org/unscear/index.html

BEIR VII report (2006) Health Risks From Exposure to Low Levels of Ionizing Radiation, National Research Council, US National Academy of Sciences. National Academy Press, Washington (http://www.nap.edu)

A summary of the cancer findings is also available (from 24 April 2006) in the Journal of Radiological Protection (Cancer consequences of the Chernobyl accident: 20 years after. vol 26(2), pages 125- (on-line doi:10.1088/0952-4746/26/2/001) .

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[1] Radioactivity from radionuclides (unstable atoms) is measured in becquerel (Bq) where 1 Bq = 1 disintegration per second and kBq/m2 = 1000 Bq of radionuclides over an area of 1 square metre. The quoted levels, 37 and 555 kBq/m2, were used by the Soviet authorities at that time to categorize the radioactivity deposition

[2] mSv is 1/1000 of 1 Sv

[3] On 24 April 2006, estimates of the Cancer Burden in Europe from the Chernobyl Accident will be published in the International Journal of Cancer and on the IARC website: www.iarc.fr.