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20 Years after Chernobyl –
A Radiation Protection Perspective

Statement by the German Commission on Radiological Protection

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1 The accident and its cause, sarcophagus and shelter

In the night of 25 to 26 April 1986, the world's worst commercial nuclear accident took place at the Chernobyl Nuclear Power Plant. The accident occurred during a technical test at reduced capacity in Unit 4 of the facility. The security systems were shut down and the faulty and improper operation of the reactor led to a power surge. The resulting explosive force of steam severely damaged the reactor buildings and completely destroyed Reactor 4, an RBMK-type reactor (Reactor Bolshoy Moshchnosty Kanalny, a high-power channel reactor). The subsequent fire in the reactor core led to a substantial release of radioactive material into the atmosphere and the ejection of fuel-containing debris from the reactor core into the area surrounding the power plant. Due to a large-scale weather situation, the release resulted in relatively high concentrations of activity over a large part of Europe and up to 1,000 km away. A surface area of some 146,000 km^2 was exposed to Cs-137 contamination greater than 37 kBq/m^2 within three countries in particular, the Ukraine, Belarus and Russia, being hardest hit. Immediately following the accident, it became crucial to isolate the destroyed portion of the reactor in order to prevent the further release of radioactive materials into the environment. To this end, under great time pressure and very difficult constraints, a so-called “entombment” or “sarcophagus” of steel and concrete was constructed around the destroyed reactor between May and October 1986. This “sarcophagus“ was designed for a lifetime of about 30 years.

Since this time, the international community, international organisations, various state-run and private institutions and Belarus, Russia and the Ukraine themselves have initiated and implemented many different aid programmes. Since 1997 and within the framework of the French-German Initiative (FGI)’s Programme 1, “Safety of the Chernobyl Sarcophagus”, data and information on building construction, equipment and systems as well as the distribution and composition (nuclide) of fuel containing materials (FCMs) on the inside of the sarcophagus have been collected. Stabilising the existing sarcophagus and safely confining the radioactive materials therein, as outlined in a plan of action developed by Ukrainian and western experts (Shelter implementation Plan, SIP), has also been carried out since 1997. Funding has come from the G7 states and the European Union by means of deposits made into a multilateral fund (Chernobyl Shelter Fund, CSF). According to an estimate by the European Bank for Reconstruction and Development, the total costs of this SIP will be approximately US$ 1.1 billion. With the shutting down of Unit 3 in 2000, only the decommissioning of the entire site will be carried out from now on.

2 Radiation exposure to the population of the Ukraine, Belarus and Russia from long-living radionuclides (apart from thyroid doses)

Over the past 20 years since the accident, radiation exposure to the general population in the Ukraine, Belarus and Russia has come as a result of external exposure to Cs-137 and other radionuclide fallout and internal exposure by way of radionuclide intake from food, water and air (primarily Cs-137 but, in the beginning, also from radioiodines). The middle effective dose cumulated (not including thyroid dose) between 1986 and 2005 by the general population living in zones contaminated by Cs-137 fallout of more than 37 kBq/m^2 (5.2 Mio people) was between 10 and 20 mSv. About 1 % of the inhabitants in these zones received radiation exposures up to some 100 mSv. 77 % of the population received doses under 10 mSv. Median doses to which the populace of the contaminated zones were exposed was generally lower than it is for people living in areas of increased natural radioactivity, e.g. in India, Brazil and China, who – through no fault of the Chernobyl accident – are exposed to radiation doses of more than 25 mSv per year from natural radionuclides without showing any noticeable health effects. The large majority of some five million people living in contaminated areas of Belarus, Russia and the Ukraine currently receive effective doses of less than 1 mSv per year (this is equivalent to the recommended dose level above which countermeasures are to be considered). Even though the existing radiation exposure in the contaminated zones is expected to decrease very slowly (about 3 - 5 % per year), about 70 % of the dose resulting from the accident has already accumulated.

Info Box: Radiation exposure

Radiation exposure is defined as energy dose, i.e. radiation energy absorbed by matter. The measuring unit for energy dose is the Gray (Gy) and is equivalent to one joule per kilogram. Exposing the human body to a few Grays of radiation causes acute radiation sickness, as happened to the emergency personnel.

In addition to energy dose, the term “effective dose” is used when quantifying health risk from radiation as far as its being a cause of malignant diseases and genetic defects is concerned. The effective dose takes into account energy dose, type of radiation and the radiation sensitivity of different organs and tissues for external as well as internal radiation. Effective dose also takes partial-body exposures into consideration. The measuring unit for effective dose is the Sievert (Sv). Since one Sievert is a very high dose, the Millisievert (mSv) is usually used when making statements of exposure within a normal range.

Info Box: Classification of the above mentioned doses

All creatures are permanently being exposed to ionising radiation from natural sources, which includes cosmic radiation, cosmogenic and terrestrial radionuclides, such as K-40, U-238, Th-232 and their decay products including Rn-222 (radon). UNSCEAR, the United Nations Scientific Committee on the Effects of Atomic Radiation, estimates that exposure to natural radiation world-wide averages 2.4 mSv per year, the typical range being between 1 and 10 mSv per year. Lifetime doses are between 100 and 700 mSv. Additional radiation exposures can be considered “low” when they are within the range of natural radiation exposure of some mSv per year.

3 Health effects in the Ukraine, Belarus and Russia

3.1 Overall mortality rate

Since the accident at Chernobyl, numerous studies have been carried out to determine whether the additional ionising radiation arising from the radioactive release increased the mortality rate in the persons affected. Of the 134 persons working in emergency services on site at the time and in whom acute radiation damage was observed, 28 died in 1986 as a consequence of their injuries. Subsequent studies suggested that there could be an increase in the mortality rate between 1991 and 1998 of a group of emergency workers (liquidators) who dealt with the aftermath of the accident in the following years and who were exposed to a dose of over 100 mSv in the first two years. In contrast, it has not yet been determined that there is an increased incidence of mortality among the population living in contaminated areas of Russia, Belarus and the Ukraine. Since a solid tumour can develop 10 years or more after exposure, advanced studies are necessary in the future so as to quantify the long-term health effects of the Chernobyl accident.

Info Box: Radiation effects

The interaction between ionising radiation (alpha, beta, gamma and other types of ionising radiation) and living matter can damage cells, which can lead to cell death or mutation. Even though the organism can repair damaged cells and dead cells can be replaced through cell division, radiation health effects can be caused when there is a breakdown of the immune system and DNA repair system in exposed individuals or their offspring. Radiation injury is divided into two categories: deterministic effects, whereby the severity of damage increases with increasing dose, and stochastic effects, whereby the probability of occurrence rather than the severity of the illness depends on the dose.

Examples of deterministic injuries include short-term effects such as skin reddening (erythema), hair loss, acute radiation sickness, temporary sterility and non-malignant long-term health effects such as cataracts. Birth defects and mental retardation caused by exposure while in the womb are also deterministic injuries. Thresholds under which injuries cannot be expected are characteristic of deterministic radiation effects. For shortterm whole body exposure, the threshold lies within the range of 0.1 Gy to 1 Gy.

Stochastic injuries are cancers in exposed individuals and genetic injury to their offspring. To date, there has been no dose threshold observed for this type of injury. It is assumed that ionising radiation raises the incidence of cancer proportionally to the radiation dose and to the spontaneous incidence rate and that there is, therefore, no threshold.

3.2 Thyroid cancer

Due to insufficient countermeasures, a large portion of the population in the affected areas received doses to the thyroid from the consumption of I-131 contaminated milk. Approximately 100,000 children and adolescents received thyroid doses in excess of 300 mSv. The incidence of thyroid cancer in this segment of the population has risen significantly since 1990. A total of 4,590 incidences of thyroid cancer were observed from 1986 to 2002 in children from Belarus and the Ukraine who were either born or were up to 18 years of age at the time of the accident. Case-control studies have shown a distinct correlation between radiation exposure following the Chernobyl accident and an increase in thyroid cancer in which about 40 % of the cases observed can be traced back to radiation exposure. Further studies have shown that the annual number of additional thyroid cancer cases is continuing to increase. The spontaneous incidence of illness, however, also rises with the increasing age of those exposed. Therefore, the actual relative risk (e.g. the ratio of the observation group to spontaneous cases) is declining. The risk coefficients of I-131 exposures following the Chernobyl accident compare well to values observed in earlier studies of radiation exposure during childhood.

3.3 Treating thyroid tumours

The prognosis (defined here in its progressive form) for thyroid cancer is good when compared to other types of cancer. The course of differentiated progressive forms (papillary and follicular) is particularly favourable. Moreover, the prognosis is dependent on the age at the time of diagnosis. The general prognosis is markedly better in children and adolescents than in adults.

Info Box: Risk

Solid tumours, leukaemia and hereditary damage caused by ionising radiation are called stochastic radiation damage. The probability of their occurrence and not their severity is dependent on dose.

These diseases also occur spontaneously. The frequency of spontaneous incidence in one year is called the "spontaneous incidence rate" and is indicated in number of cases per 100,000 persons and per year (i.e. 10^5 person-years). The incidence rate of thyroid cancer (in the reference period of the study of the area around Chernobyl) among 1- to 33-yearolds was 2.5 cases/10^5 person-years in the USA (caucasians), was 2.1/10^5 person-years in Canada, was 1.0/10^5 person-years in the Czech Republic, was 0.8/10^5 person-years in Holland and was 0.6/10^5 person-years in England. In general, the incidence rate of solid tumours increases markedly with age. If medical treatment is carried out, the mortality rate from thyroid cancer is marginal.

The incidence rate of stochastic injuries increases with the effects of ionising radiation. In radiation protection, it is assumed that the increased incidence rate is proportional to radiation dose and that there is no dose threshold.

The number of cases of tumours per person and over a time period is referred to as absolute risk. A common expression for risk caused by radiation is relative risk (RR) or excess relative risk (ERR). The RR is equal to the incidence rate following exposure divided by the spontaneous incidence rate. The ERR is equal to the additional incidence rate following exposure divided by the spontaneous incidence rate. An RR of 2 is the same as an ERR of 1 and means that the additional exposure-induced incidence rate is the same as the spontaneous incidence rate. In order to designate an RR or ERR value, the associated dose must always be indicated. One can also designate the RR or ERR per unit of equivalent dose in order to characterise stochastic radiation effects.

The spontaneous lifetime risk of dying as the result of a solid tumour is more than 0.2 in Germany and other industrial countries (e.g. approximately 20 - 30 % people die from tumours). The International Commission on Radiation Protection (ICRP) estimates that the lifetime radiation risk of developing a lethal form of cancer rises across all age groups linearly to dose with an average gradient of 5×10^{-2} per Sv (0.08×10^{-2} per Sv for thyroid cancer).

According to available data mapping the progression of the disease, the survival rate between 1992-2002 of the 1,152 thyroid cancer cases (almost exclusively of papillary histology) among Belarussian children, who became sick following the Chernobyl accident, was approximately 99 %. Since a not insignificant number of thyroid cancer cases within the Belarussian community (about 20 %) were only diagnosed once they were in the advanced stage, a reliable assessment of the prognosis for this segment is only possible after some decades.

3.4 Solid tumours and leukaemia

It has been substantiated scientifically that ionising radiation can trigger both solid tumours as well as leukaemia. However, since cancer commonly occurs and since the additional dose to which the population of the affected countries was exposed was comparatively small, an increase in the cancer rate could not be proven for this group of people – at least not yet. Even an increase in leukaemia among children living in contaminated areas could not be determined. Since radiation-induced solid tumours only manifest themselves many decades after the exposure, radiation sensitive organs, e.g. women's breasts, should continue to be checked. In one study, an increased number of leukaemia cases and first reports of higher cancer rates have been found among the emergency workers, who were exposed to higher dose. Results of other studies, however, have been contradictory. Therefore, studies should continue to be carried out before a final assessment can be made.

3.5 Additional health effects

In addition to cancer, a series of additional health effects possibly caused by the nuclear catastrophe in Chernobyl have been studied. Such adverse health effects to the population and emergency workers in the former Soviet Union following exposure include eye cataracts, cardiovascular disease, changes in the immune and reproductive systems and possible anomalies among newborns. Distinct changes in the immune system could not be observed though it is possible that cardiovascular disease increased among the liquidators. However, an increase in cataracts following radiation doses greater than 250 mSv has been determined. There is no evidence of an increase in birth defects or infant mortality.

Info Box: Epidemiological studies

Conclusions on additional risk attributed to radiation can be obtained from epidemiological studies. There are different types of epidemiological studies, which vary greatly in regards to their informative value and ability to establish a connection between exposure and effect.

Case-control studies examines whether a person suffering from, or who has died from, a specific illness has been exposed more often or more heavily than healthy persons in a control group to the noxa in question (in this case, ionising radiation). The relative risk can be determined in case-control studies.

Group studies pose the question of whether exposed persons suffered or died more frequently from certain illnesses during the observation period than did non-exposed persons. Both the determination of absolute and relative risk are allowed.

Ecological studies vary from case-control studies and cohort studies in that data for groups of persons rather than individuals is upraised. These studies present information on the frequency of the disease and cause of death against the backdrop of the physical and social environment. The main disadvantage of ecological studies is the danger of ecological bias, such as a misclassification of cases within the dose group or unverified additional risk factors, which may lead to mistakes in estimating radiation risk.

4 Situation in Germany

4.1 Radiation exposure in Germany

The estimation of radiation exposure in Germany from the Chernobyl accident in the most highly contaminated area of Southern Bavaria amounts to an effective dose over the next 50 years equivalent to one year's radiation exposure to natural radioactive substances. In most parts of Germany, which were not as affected by radiation contamination, the medium radiation exposure is less than a factor of 4 (effective dose is about 0.5 mSv, thyroid dose is about 0.5 mSv for adults and about 1.5 mSv for people who were children at the time of the accident). Forest products (game, mushrooms) are the only foodstuffs today, which still afford appreciable contributions to activity incorporation by individual persons.

4.2 Health effects in Germany?

Additional radiation doses in Germany caused by the nuclear accident at Chernobyl were within the range of natural radiation exposure. However, a series of studies have voiced a suspicion that there is a relationship between observations made in Germany (e.g. Down's Syndrome, infant mortality, leukaemia, neuroblastoma and cleft lip and palate) and the ionising radiation emitted as a result of the Chernobyl accident. Arguing against a causal connection between the ionising radiation caused by Chernobyl and the observations mentioned are, above all, negative findings from other parts of Europe, which – in part – received higher radiation doses and the fact that no biological mechanism has been found to date that could make such a causal connection in the extent described plausible.

4.3 Consequences of the nuclear accident at Chernobyl

The accident at the Chernobyl Nuclear Power Plant prompted the German government as well as governments of neighbouring countries, the EU and many international organisations to take up a series of measurements to improve emergency response. Alongside measures to improve monitoring environmental radioactivity, the development of systems for supporting crisis management as well as agreements for the national and international exchange of information were also initiated.

5 Mental and psychological effects

The consequences of Chernobyl would not be recorded completely, if they were limited to measurable radiological effects to health, flora, fauna, the environment, economics and politics. More striking was the effect it had on the way people thought and perceived themselves. The mental and psychological effects in Germany triggered by the event that took place on 26 April 1986 were highly variable both individually and collectively and were by no means in relationship to the extent and dispersion of radiation dose. A comparison of national and administrative measures with other countries shows a very different understanding of the definitions of threat and anxiety. The suspicion that Chernobyl was, to a large extent, an information and communication disaster has been confirmed using available data. Communication was too late, untrue, played down and inadequate. An example of this can be seen within the context of Soviet information politics and international political pressure. Another can be seen in how the German population dealt with the imperceptible dangers of modern ABC (atomic, biological and chemical) weapons, how it reacted to contradictory and unavailable information and then overreacted when they had the impression that any real dangers were downplayed. Not only did this lead to initiatives, protests, demonstrations and changed behavioural, consumer and nutritional strategies, overreaction also led to hoarding and self-evacuation as well as disposal and decontamination campaigns (for instance, “whey”), which was more of a symbolic action. As with Seveso, Chernobyl led to massive changes. The possible risks of industrial systems are, more than ever, proactively thought out, controls and preventative measures have been put into the foreground, and the population itself is involved in averting danger by means of area-wide measurement and information systems.