

13. Radiation emergencies

13.1 Health consequences of radiation

Radiation can kill or damage living cells, but as many of the billions of cells in the human body are replaced every day, minor exposures to radiation may have little or no effect on an individual. Major exposures to radiation, however, can have health effects which can be divided into *deterministic*, or *acute* effects, and *stochastic*, or *late* effects. Deterministic effects include skin burns, radiation sickness and death. Stochastic effects, on the other hand, include cancers and inheritable defects that result from damage to the genetic material in cells.

Radiation emergencies can have severe psychological effects on the victims, as the fear of an unfamiliar, invisible and potentially terrible danger causes acute stress. Such stress and its associated problems can arise even when radiation exposure is low or insignificant.

13.2 Radiation from nuclear incidents

There are several ways in which a person can become overexposed to ionizing radiation. In peacetime, the more likely ways are accidents in nuclear power plants or research institutions dealing with radioactive materials; and undue exposure to radioactive waste or radioactive source used in industry, medicine and research laboratories. More recently, the threat of terrorist acts that involve nuclear facilities, or the theft of radioactive substances, has become more prominent.

The medical and health responses to a radiation emergency depend on its magnitude. The International Nuclear Event Scale (INES), with eight levels, is used to inform the public about the severity of events at nuclear facilities (see Table 13.1).

13.3 International and local response to a major nuclear accident in compliance with the Convention on Early Notification and Assistance Convention

In the case of a nuclear accident, the level of radiation hazard for the population depends upon: the quantity and type of radionuclides released into the environment; the distance of the populated areas from the source of radioactive release; the type of buildings; the population density; the meteorological conditions at the time of the accident; the season of the year; the character of agricultural development in the area; water supplies; nutritional habits; and the nutritional status of the population.

In nuclear reactor accidents that release radioactive material into the atmosphere, the following routes are expected to result in radiation injury to the population:

- direct external irradiation with γ -rays from the passing radioactive cloud;
- internal irradiation from inhaling radioactive aerosols (inhalation hazard);
- contact radiation from radioactive fallout on the skin and clothes;
- total external irradiation of the population with γ -rays from radioactive fallout on the soil and local objects (buildings, constructions etc.);
- internal irradiation from consuming water and local food products contaminated by radioactive substances.

Table 13.1 International Nuclear Event Scale (INES), used to inform the public about the severity of events at nuclear facilities

Level	Description of event
Level 0 (deviation)	An event with no safety significance.
Level 1 (anomaly)	An event beyond the authorized operating regime, but not involving significant failures of safety provisions, significant spread of contamination, or overexposure of workers.
Level 2 (incident)	An event involving significant failure of safety provisions, but with sufficient in-depth defence remaining to cope with additional failures; and/or resulting in a dose to a worker exceeding a statutory dose limit; and/or leading to the presence of activity in on-site areas not expected by design and which require corrective action.
Level 3 (serious incident)	A near-accident, where only the last layer of in-depth defence remained operational; and/or involving severe spread of contamination on-site or deterministic effects to a worker; and/or a very small release of radioactive material off-site (i.e. critical group dose of the order of tenths of a mSv).
Level 4 (accident without significant off-site risk)	An accident involving significant damage to the installation (e.g. partial core melt); and/or overexposure of one or more workers that results in a high probability of death; and/or an off-site release with a critical group dose of a few mSv.
Level 5 (accident with off-site risk)	An accident resulting in severe damage to the installation, and/or an off-site release of activity radiologically equivalent to hundreds or thousands of TBq of ^{131}I , likely to result in partial implementation of countermeasures covered by emergency plans. Examples: the 1979 accident at Three Mile Island, USA (severe damage to the installation) and the 1957 accident at Windscale, UK (severe damage to the installation and significant off-site release).
Level 6 (serious accident)	An accident involving a significant release of radioactive material, and likely to require full implementation of planned countermeasures, but less severe than a major accident. Example: the 1957 accident at Kyshtym, USSR (now in the Russian Federation)
Level 7 (major accident)	An accident involving a major release of radioactive material with widespread health and environmental effects. Example: the 1986 accident at Chernobyl, USSR (now in Ukraine).

During a major nuclear accident, the following three phases are identified:

- **Early phase**—from the threat of a serious release to the first few hours after the beginning of a release;
- **Intermediate phase**—from the first few hours, to 1–2 days after the start of the release;
- **Recovery phase**—from some weeks to several years after the start of the release.

Information presented in Annex 4 (Tables 1–4) gives a general summary of the actions of IAEA, WHO, other international organizations, and local health authorities in

response to nuclear accidents, in compliance with the Convention on Early Notification and the Assistance Convention.

In the event of a nuclear accident, the criteria for implementing countermeasures to protect the population will depend on the phase of the accident. At the early and intermediate phases, decisions should be based on a comparison of the estimated radiation doses (calculated at the start of the accident) and intervention levels of doses given in Tables 1 and 3 of Annex 5. The dose criteria for taking protective countermeasures at the early phase are often crude estimates taken over a short period of time. During the recovery phase, decision-making is based on intervention levels of doses presented in Table 2 of Annex 5. The dose criteria for the relocation of the population refer to the estimated doses of both external and internal radiation during the first year. The dose criteria for implementing restrictions on consuming radionuclide-contaminated food products and drinking-water (Annex 5, Table 4) refer to estimated annual doses of internal radiation from radionuclides consumed in food and water.

13.4 The role of WHO in a radiation emergency

WHO, as the lead United Nations agency for health issues, has the responsibility for shaping, coordinating and initiating health-related emergency assistance programmes at the global level. WHO has established a network of collaborating centers (REMPAN) for promoting radiation emergency medical preparedness and for providing practical assistance and advice to countries in the event of an emergency involving radiation overexposure. The roles of WHO and REMPAN in radiation emergencies are outlined in Table 13.2.

13.5 Mitigation of effects

In general, the first priority is to limit the exposure to radiation that occurs primarily through radioactive fallout, either by evacuation or by sheltering the affected population. Depending on the strength of the explosion or release and the prevailing meteorological conditions (e.g. wind and precipitation), a radius of between 30 and several hundreds of kilometres from the release epicentre should be declared a priority area for action. Sheltering may be considered a preliminary solution before evacuation. Suitable sheltering sites include nuclear shelters, caves, mines and any place with a barrier of solid substances between the radiation and people. Radiation-free air, water and food will be required to diminish the hazard.

Victims of radiation from nuclear explosions should be moved as quickly as possible to an appropriate medical establishment. In some types of incidents, hundreds or even thousands of people may need to be examined for external or internal contamination. Such examinations require specialized equipment. The scope of—and the need for—decontamination will depend on whether there is evidence of body-surface contamination. Contaminated clothing will need to be handled appropriately and disposed of according to accepted procedures. Contaminated individuals will need to be thoroughly showered and be provided with uncontaminated clothing. Any illness should be treated immediately. If there is evidence of internal contamination with radioactive iodine (I^{131}), stable iodine prophylaxis is needed to avoid excessive thyroid radiation doses and, especially in young people, to reduce the risk of thyroid cancer in later life. See Box 13.1 for further information and recommended stable iodine dosages.

Depending on the results of diagnostic investigations, substantial surgical treatment may be required. This can only be provided by competent, trained physicians and nurses operating in sterile treatment facilities.

Table 13.2 Roles of WHO and REMPAN in a radiation emergency

Type of accident	Roles of the collaborating centres within REMPAN
A major release of radioactive material from a nuclear reactor	<ul style="list-style-type: none"> ■ provide assistance and advice for the management of exposed individuals ■ provide a team for on-site emergency treatment ■ transfer (if possible and necessary) severely exposed patients to collaborating centres for specialized medical care ■ provide a survey team for rapid external radiation monitoring and/or contamination surveys with appropriate equipment ■ provide facilities and staff for medical investigations and treatment ■ assist in the development of measures necessary to limit health effects ■ provide follow-up medical supervision and treatment
High radioactivity sources leading to severe exposure of some individuals	<ul style="list-style-type: none"> ■ visit the accident site to identify and isolate the source of radiation ■ make an assessment of likely exposure ■ recommend appropriate medical treatment ■ transfer patients to specialized medical facilities (if necessary and requested) ■ assist in developing procedures to strengthen countries' abilities to manage such accidents themselves
Excessive exposure of patients and/or medical staff due to the administration of radiation for medical purposes	<ul style="list-style-type: none"> ■ circulate information relating to such incidents for the benefit of Member States

Box 13.1 Stable iodine prophylaxis

Exposure to radioisotopes of iodine following an accidental release can result in a significant increase in thyroid cancer, especially in young children. Inhaled and ingested radioactive iodine is preferentially taken up by the thyroid, and young children's thyroids are particularly sensitive to radiation.

Stable iodine blocks the uptake of radioactive iodine by the thyroid. It is available in a number of forms and is most effective when taken as close as possible to the first exposure to radioactive iodine. A single dose will normally protect against inhalation exposure. If a release lasts longer than a day, the preferred response, if practicable, is evacuation. Further doses to protect against radiation exposure from ingesting radioactive food may be required if uncontaminated food supplies are not available. The recommended single doses are:

Age	Recommended dosage ¹
>12 years	100 mg
3–12 years	50 mg
1 month to 3 years	25 mg
<1 month	12.5 mg

¹equivalent mass of iodine—the iodine dose is usually taken either as potassium iodate or potassium iodide.

When radionuclide contamination spans national boundaries, international and national authorities would normally take the lead role in radiation emergencies. However, local authorities can play a key role in alleviating the health consequences of radiation emergencies (see Box 13.2).

Care must be taken when handling victims who have been externally contaminated by radionuclides, as the radiation that they emit can affect helpers. Their clothes must be changed and they must be bathed. In handling them, especially in the initial stages, helpers should wear thick clothing and gloves.

Many of the workers in nuclear power plants and research institutions are likely to be technically well-qualified and experienced. They will often be an integral part of the emergency response plan with roles in both the monitoring and cleanup efforts that utilize their broad experience.

If it is necessary to evacuate the population in the vicinity of the accident, radiation levels in air, water and food must be monitored. Health authorities must be prepared to provide safe water and food if these have been contaminated.

Prompt, honest and authoritative warning is important to enable people to evacuate or shelter from the radioactive plume (farmers, construction workers, forest workers, and other outdoor workers may be less accessible and more difficult to inform). Monitoring fallout in down-wind regions and countries is essential. The exposure of standing crops and the uptake of radionuclides by farm animals is an important consideration.

Box 13.2 Role of the local authority¹

Affected individuals will often turn first to the local authority for advice, treatment and reassurance. Preparation and planning for radiation emergencies should not be viewed as the concern of central governments only.

Local authorities that are prepared and have planned for radiation emergencies can assist in solving public-health problems in a number of ways.

Before an emergency they can:

- inform and train doctors and other front-line professionals to whom the public are likely to turn in an emergency;
- inform the public about the possibility of an emergency, its probable consequences and possible remedial actions.

During an emergency they can:

- provide information, guidance and reassurance to the public;
- provide stable iodine prophylaxis, where appropriate;
- ensure the availability of immediate medical treatment to those who require it;
- provide advice on the safety of food and beverages.

After an emergency they can:

- regulate the production and distribution of food;
- organize the provision of long-term health care to victims;
- support medical, psychological and social recovery.

Addressing public anxiety is a difficult and complex task that requires careful consideration. The public must be informed of the nature and extent of any radiation emergency and the likely effects on health. On the other hand, inappropriate and excessive reactions on the part of the authorities may unjustifiably heighten fears and lead to crowding at medical facilities, as individuals seek information and treatment.

¹ Source: World Health Organization (1997b).

Unless uncontaminated fodder and water can be provided to cows, milk may have to be condemned. A programme to monitor the radioactivity of food may need to be initiated, depending on the concentration of radionuclides in the environment (Eheman, 1989).

Depending on the levels of radiation and the nature and quantity of the radioisotopes in the fallout, large-scale evacuation of populations from contaminated areas may be required for long periods of time (World Health Organization, 1996b). The above intervention measures, and other measures as required, should be undertaken in accordance with the intervention levels developed by FAO, IAEA, OECD/NEA, PAHO and WHO (International Atomic Energy Agency, 1996). See Table 1 of Annex 4 for further details. Immediately after exposure to radiation (before screening by specialists), both the alleviation of symptoms and psychological support of victims are very important. It must be remembered that vomiting, the most common initial symptom of a radiation overdose, can also be of psychosomatic origin.

13.6 Inadvertent exposure to radioactive material

Radioactive materials are used for many industrial, research and therapeutic purposes and there is always the possibility that people will be exposed inadvertently. In general, industries and institutions handling radioactive materials have high safety standards and well-established handling procedures, and their workers are generally well protected. The high qualifications of these personnel, and the fact that they are usually well organized, give them the collective strength needed to fight for a safe working environment.

Apart from medical procedures for which a benefit is clearly defined, the most likely sources of significant exposure to radioactive material are discarded or stolen sources whose dangerous properties are not recognized by the perpetrators. Such accidents usually come to light when a radioactive source is found to have been mislaid. Prompt notification of the appropriate authorities and the use of the mass media should make the community aware of the danger. Sometimes the first indication of accidental exposure is the appearance of people with radiation injuries, e.g. radiation burns. When this happens, detailed questionnaires should be used, both to clarify the circumstances leading to the exposure and to trace other possible victims. Compounding the problem is the fact that radiation cannot be perceived by the senses, and that its first symptoms are very unspecific. An account of a radiation accident in Brazil is given in Box 13.3.

The disposal of radioactive wastes is another potential risk. Waste is produced from various steps of the nuclear fuel cycle, in the medical use of radioisotopes, by the military, and from the widespread industrial use of sealed radiation sources. Safety criteria for disposing of such wastes do exist and are quite restrictive. However, most countries

Box 13.3 Poverty and radiation exposure in Brazil

In September 1987, metal scavengers dismantled a canister from a radiotherapy machine in an abandoned medical clinic in the city of Goiânia, in the State of Goiás, Brazil. The canister contained almost 1400 curies of caesium-137. Over the following two weeks, children played with the luminous blue caesium chloride and it was widely distributed throughout the community. A number of the slum dwellers began to immediately exhibit signs of radiation sickness—loss of appetite, nausea, vomiting and diarrhoea. By the time authorities were aware of the situation more than 250 people had been exposed, 104 individuals showed evidence of internal contamination and within 4 weeks four had died.

The cause of the accident was the lack of regulation by the responsible authorities and its severity was exacerbated by the public's lack of knowledge about radiation, the slow response and the lack of resources available.

that produce radioactive wastes still have problems with disposal, especially for intermediate and high-level wastes. High-level waste may have to be safely stored for thousands of years, which requires deep burial of material in corrosion-resistant containers in a geologically stable region. This, and other requirements for a repository, mean that many countries are still addressing the question of disposal. The transport of radioactive material is also a hazardous procedure, and the potential for injury to human health always exists. However, codes of practice for the transport of radioactive materials exist in many countries and more than sixty IAEA member states have adopted the agency's Regulations for Safe Transport of Radioactive Material (Rawl, 1998).

13.7 Further information

For further information on radiation emergencies and health, see: World Health Organization (1984b), World Health Organization (1987b), World Health Organization (1989c), International Atomic Energy Agency (1994), Organization for Economic Cooperation and Development & Nuclear Energy Agency (1994), International Atomic Energy Agency (1995), World Health Organization (1995d), International Atomic Energy Agency (1996), World Health Organization (1997b), and International Federation of Red Cross and Red Crescent Societies (1998).