Radiation emergencies

Health consequences of radiation

Radiation can either kill or damage living cells. As many of the billions of cells in the human body are replaced every day, minor exposures to radiation may have little or no appreciable 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, which 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. It must be realized that such stress and its associated problems can arise even when radiation exposure is low or insignificant.

Radiation from nuclear incidents including accidents in nuclear power plants or research institutions or from nuclear warfare or terrorism

There are several possibilities that can lead to overexposure of persons to ionizing radiation. Of these, the more important in peacetime 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, a threat of overexposure of populations to radiation due to terrorism involving nuclear facilities or the theft of radioactive substances, has become more prominent.

The medical and health response to a radiation emergency depends on its magnitude. The International Nuclear Event Scale (INES) is a scale that includes eight levels and is used to inform the public about the severity of events at nuclear facilities (see following box).

International Nuclear Event Scale (INES) is used to inform the public about the severity of events at nuclear facilities. This scale includes eight levels as indicated below.

Level 0 (deviation)	An event with no *safety* significance.
Level 1 (anomaly)	An event beyond the authorized operating regime, but not involving significant failures in safety provisions, significant spread of contamination or overexposure of *workers*.
Level 2 (incident)	An event involving significant failure in *safety* provisions, but with sufficient defence in depth 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 *defence in depth* 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* resulting in a high probability of death, and/or an *off-site* release such that the *critical group dose* is of the order 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. e.g. the 1979 accident at Three Mile Island, USA (severe damage to the installation), or 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*. e.g. the 1957 accident at Kyshtym, USSR (now in Russian Federation)
Level 7 (major accident)	An *accident* involving a major release of *radioactive material* with widespread health and environmental effects. e.g. the 1986 accident at Chernobyl, USSR (now in Ukraine).

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 principle radionuclides released into the environment, the distance of the populated areas from the source of radioactive release, the type of buildings and the density of population, meteorological conditions at the time of the accident, season of the year, character of agricultural development in the area, water supplies and nutritional habits and status of the population.

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

- external gamma irradiation brought by the passing radioactive cloud;
- internal irradiation from inhaling radioactive aerosols (inhalation hazard);
- contact radiation due to deposition of radioactive fallout on the skin and clothes;
- total external gamma irradiation of the population due to deposition of radioactive fallout on the soil and local objects (buildings, constructions etc.); and
- internal irradiation resulting from water consumption and local food products contaminated by radioactive substances.

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 after the start of the release to one or two days; and
- **Recovery Phase** – may extend from some weeks to several years.

Information presented in the Annex I (Tables 1-4) gives a general summary of the actions of IAEA, WHO, other international organizations and local health authorities in response to the nuclear accident in compliance with the "Convention on Early Notification" and "Assistance Convention" .

Criteria for decision-making on the implementation of countermeasures to protect the population from radioactive materials released due to a nuclear accident depend on the phase of the accident. At the early phase and intermediate phase, decisions should be taken on the basis of a comparison between the estimated radiation doses (calculated at the start of the accident) and intervention levels of doses given in Tables 1 and 3 of the Annex II. II The dose criteria for taking protective countermeasures at the early phase refer to often crude dose estimates during a short period of time. At the recovery phase, decision-making is based on intervention levels of doses presented in Table 2 of the Annex II. 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 the implementation of restrictions on the consumption of radionuclide contaminated food products and drinking water refer to estimated doses of internal radiation by radionuclides in food and water consumed within a year (Table 4, Annex II).

Role of WHO in a radiation emergency

The World Health Organization, 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 centres, REMPAN. The role of the collaborating centres in radiation emergencies is outlined in the following Box.

Role of WHO in a radiation emergency

WHO has established a network of collaborating centres - REMPAN - for the promotion of radiation emergency medical preparedness and for practical assistance and advice to countries in the case of overexposure from any source of radiation,

Type of accident	Roles of the collaborating centres within REMPAN
A major release of radioactive material from a nuclear reactor	• provide assistance and advice in the management of exposed individuals; • provide a team for on-site emergency treatment • transfer (if possible and necessary) of 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; and • provide follow-up medical supervision and treatment
High activity sources leading to severe exposure of some individuals	• visit the accident site in order to identify and isolate the source of irradiation; • make an assessment of likely exposure; • recommend appropriate medical treatment • transfer of patients to specialized medical facilities (if necessary and requested); and • assist in the development of procedures to strengthen the countries abilities to manage such accidents for themselves; • circulate information relating to such incidents for the benefit of member states in general
Excessive exposure of patients and/or medical staff due to the administration of radiation for medical purposes	

Mitigation of effects

In general the first priority is to limit the exposure to radiation which 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 kilometers from the explosion epicentre should be declared a priority area for action. Sheltering may be considered a preliminary solution before evacuation. Suitable sheltering sites are refuges, caves, mines, and, in general, any place where there is a barrier of solid substances between radiation and humans. 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. The person will require thorough showering and the provision of uncontaminated clothing. Any illness should be treated immediately. Where there is evidence of internal contamination with radio-active 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 following box for further information and recommended dosages).

Stable iodine prophylaxis

Exposure to radioisotopes of iodine following the accidental release of radioiodine can result in a significant increase in thyroid cancer in, especially, young children. Inhaled and ingested radioiodine is preferentially taken up by the thyroid and, compared with adolescents and adults, young children's thyroids are more radiosensitive.

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. If a release lasts longer than a day the preferred response, if practicable, is evacuation. Further doses to protect against the ingestion pathway may be required if uncontaminated food supplies are not available. The recommended single doses are:

Age	Recommended dosage[a]
>12 years	100mg
3–12 years	50mg
1 month to 3 years	25mg
<1 month	Single does 12.5mg

[a] equivalent mass of iodine – dose is usually taken as either potassium iodate or potassium iodide

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.

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 the alleviation of health consequences of radiation emergencies (see following box).

Role of the local authority[1]

Central government authorities play a large part in all but very minor radiation emergencies. 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 the solution of 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 the probable 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 the victims.
- Support medical, psychological and social recovery.

Addressing public anxiety is a difficult and complex task, and requires very careful consideration. The public must be informed of the nature and extent of any 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 (1997a).

Care must be taken in the handling of victims 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 that utilize their broad experience in both the monitoring and cleanup efforts. If it is necessary to evacuate the population in the vicinity of the accident, radiation levels in air, water and food must be monitored and health authorities must be prepared to provide safe water and food if these have been contaminated.

Prompt, honest, and authoritative warning is very important to enable people to evacuate or to shelter from the plume (farmers, construction and forest workers, and other outdoor workers may be less accessible and more difficult to inform). The monitoring of fallout in down-wind regions and countries is essential. The exposure of standing crops and the uptake of radionuclides by farm animals is a very important consideration. Unless uncontaminated fodder and water can be provided to cows, milk may have to be condemned. A program monitoring the radioactivity of food may need to be inititiated depending on the concentration of radionuclides in the environment (Eheman, 1989, pp. 120–121).

Depending on the levels of radiation and the nature and quantity of the radioisotopes contained in the fallout, authorities should realize that large-scale evacuation of populations from contaminated areas may be required for long periods of time (World Health Organization, 1996c). 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). 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 the most common initial symptom of a radiation overdose - vomiting - can also be of psychosomatic origin and is one that can be rapidly imitated.

Inadvertent exposure to radioactive material

The uses of radioactive materials for industrial, research and therapeutic purposes are manifold and as a result, there is always the possibility of inadvertent exposure of humans. In general, industries and institutions handling radioactive materials have high safety standards and well-established handling procedures and the 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 work environment.

Apart from medical procedures for which a benefit is clearly defined, the most likely source of significant exposure to radioactive material is 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 to 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 anamnesis questionnaires should be used, both to clarify the circumstances leading to the exposure and to trace other, as yet unknown, victims. The fact that radiation cannot be perceived by the senses, and that its first symptoms are very unspecific, compounds the problem. An account of a radiation accident in Brazil is given in the following box:

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 Goiania, in the State of Goias, Brazil The canister contained almost 1400 curies of caesium-137. Over the following two weeks the luminous blue caesium chloride was played with by children and 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 diarrhea. By the time authorities were made aware of the situation more than 250 people had been exposed, 104 individuals showed evidence of internal contamination and within four weeks, four of these people had died.

The severity of the accident was exacerbated by the lack of radiation knowledge by the public. The cause of the accident was the lack of regulation by the responsible authorities. The lack of adequate response time and materials contributed to the casualties and fatalities.

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 sources. Safety criteria for such disposal exist, and are quite restrictive. However most countries which produce radioactive wastes still have problems with disposal, especially for intermediate and high level waste. High level waste may have to be safely stored for thousands of years. This 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 Agencies Regulations for Safe Transport of radioactive Material (Rawl, R., Transport Safety, IAEA Bulletin 40, #2, 18-20, 1998)

Further information

For further information on radiation emergencies and health, see World Health Organization (1989d), International Atomic Energy Agency (1994) Organization for Economic Co-operation and Development (1994), International Atomic Energy Agency (1995), World Health Organization (1995), International Atomic Energy Agency (1996), and International Federation of Red Cross and Red Crescent Societies (1998).

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[1] See also: Web Site <http://www.oes.ca.gov/oeshomep.nsf/all/cep/$file/cep.pdf>

Annex I

INTERNATIONAL AND NATIONAL ACTIONS IN RESPONSE TO A RADIATION EMERGENCY

Information presented below summarizes in general the actions of WHO, IAEA, other international organizations and local health authorities in response to the nuclear accident in compliance with the "Convention on Early Notification" and "Assistance Convention" in Tables 1-4.

Table 1. International response at the early phase of the accident

IAEA	WHO/HQ	Regional offices	Other international organizations
1. Establish direct telephone links with the accident State and those States deemed to be possibly affected. 2. Identify possibly affected states within a radius of 1000 km from the release location. 3. Contact affected states and provide them with special numbers for contacting the Agency 4. States outside the 1000 km zone will also be rapidly informed of the release, but not on the priority basis.	1. Develop communication with Regional Offices and Member States, including links with the Ministries of Health of the accident country, affected states and those that may be affected. 2. Request accident state, IAEA and WMO to provide computer modelling maps of radioactive cloud. 3. Request ICRP and IRPA to assist in evaluation of possible health consequences. 4. Request REMPAN and GERMON members to provide WHO with information on readiness to assist (upon request) the accident country and affected states (specify type of assistance, including man-power and finance). 5. Contact Regional Offices to mobilize resources (including financial) for the accident countries and affected states. **6.** Follow-up of the accident development and, if necessary, convene expert group meeting to obtain recommendations.	1. If information about the accident was obtained from an accident or affected country, inform WHO/HQ. 2. Establish com-munications with WHO/HQ, Ministry of Health of accident and affected countries, WHO/REMPAN members in the region. 3. Undertake actions according to emergency plan. **4.** Regularly inform WHO/HQ about any progress in the development of the situation.	**FAO** - Collect and assess information from IAEA or the accident country or affected countries, on possible food contamination. Disseminate relevant information. **WMO** - Information on the direction of any released radioactive material should be issued regularly by designated WMO centres, for transmission to states and international organizations. **UNEP** - Provide relevant environmental and natural resources information through GEMS, GRID and GERMON for the analysis of data **UNOCHA** - Assist in coordination of activities for mobilizing resources to overcome consequences of the accident. **UN International Emergency Network** -Assist in distribution of relevant information after a radiation emergency.

Table 2. Priorities of National and Local Response

National and Local level	1. First medical care to radiation victims 2. The accident State and affected States provide IAEA and FAO with information of food and drinking water contamination. 3. Implementation, if necessary, of the following applicable and possibly essential countermeasures: sheltering, radioprotective prophylaxis, iodine prophylaxis, body protection, evacuation, personal decontamination. (See Annexes II and III) 4. If necessary, request assistance of international community.

Table 3. International and local response at intermediate phase of the accident

IAEA	**WHO/HQ in cooperation with WHO/ROs**		**Local level**
	No request for assistance	Request [1]	
1. Transmitting request for assistance and relevant information 2. Offering its good offices to coordinate assistance to those states requesting support. 3. Provide appropriate resources allocated for the purpose of conducting an initial assessment of the accident or emergency 4. Develop appropriate monitoring programmes,	1. Monitor and study the situation. 2. Communicate between WHO/HQ, WHO/ROs, Ministries of Health of the affected countries, and information exchanges, etc 3. Maintain REMPAN & GERMON in operational readiness 4. Mobilize resources. 5. Request additional information from the accident country,	1. Acknowledge the receipt of the request. Notify the requesting state directly or through IAEA if it is in a position to render the requested assistance and terms of the assistance that might be rendered. 2. Within the limits of WHO/HQ and WHO/RO's capability, identify and notify the IAEA of experts, equipment and materials which could be made available for provisional assistance. 3. Inform IAEA and other State Parties (directly or through IAEA) of WHO competent authorities and points of contact. 4. Request information in compliance with the check-list. 5. Request additional information, if the information is seen at WHO/HQ as	1. Specify the scope and type of assistance required. 2. Provide the assisting party with information as may be necessary to determine the extent to which it is able to meet the request. 3. Unless otherwise agreed: provide the overall direction, control, coordination and supervision of the assistance; designate in consultation with the requesting state a person in charge who should exercise his supervision in cooperation with the appropriate authority of the requesting state. 4. Provide local facilities and services for the proper and effective administration of the assistance. 5. Ensure the protection of personnel, equipment and materials brought into its

[1] May come directly from the accident or affected countries, via IAEA, or other international intergovernmental organizations

procedures and standards 5. Send radiological and emergency teams to the site of the accident.	affected country, IAEA and other relevant organizations. 6. Convene meeting of experts, if necessary, to obtain relevant recommendations.	insufficient. 6. Inform the country about the type of assistance which will be sought by WHO from its REMPAN Collaborating Centres. 7. Describe the Collaborating Centres that will be approached. 8. Ask the selected Collaborating Centre for available assistance. 9. Establish link between the requested country and assisting centre(s), inform REMPAN of the outcome of the request. 10. Keep all REMPAN centres informed about the details of the accident and progress in its management.	territory by or on behalf of the assisting party. 6. Ensure the return of the equipment and materials to the assisting party. 7. Inform WHO about the termination of assistance. 8. Applicable countermeasures sheltering; radioprotective prophylaxis; body protection; decontamination of areas; evacuation. 9. Applicable or possibly essential countermeasures: evacuation; personal decontamination; relocation; food control.

Table 4. **International and local actions at the Recovery Phase of the accident**

International level	**Local level**
1. Actions depend on the requests of the accident countries or affected countries. They may relate to providing humanitarian assistance to the accident country or affected countries and facilitating medical and epidemiological follow-up.	1. Applicable countermeasures - personal decontamination - relocation - control of access 2. Applicable and possibly essential countermeasures - food control - decontamination of areas

ANNEX II

Selected information from the International Basic Safety standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Jointly sponsored by FAO, IAEA, OECD/NEA, PAHO, WHO, Vienna 1996.

The management of accident situations outlined in the standards are based on the ICRP principles for planning and deciding interventions to cope with a radiological emergency. These principles are as follows:

- All possible efforts should be made to prevent serious deterministic health effects;

- The intervention should be justified, in the sense that introduction of the protective measure should achieve more good than harm;

- The levels at which the intervention is introduced and at which it is later withdrawn should be optimized, so that the protective measure(s) will produce a maximum net benefit.

The main criterion for deciding on intervention is the mean individual dose which is expected to be avoided by the intervention.

Dose levels at which intervention is expected to be undertaken under any circumstances (be justified) are given in Tables 1 and 2.

Table 1. Intervention level of dose for acute exposure

Organ or tissue	Projected absorbed dose (Gy) to the organ or tissue in less than 2 days
Whole body (bone marrow)	1
Lung	6
Skin	3
Thyroid	5
Lens of the eye	2
Gonads	3
Note:	The possibility of deterministic effects for doses greater than about 0.1 Gy (delivered over less than two days) to the foetus should be taken into account in considering justification and optimization of actual intervention levels for immediate protective action.

Table 2. Intervention level of dose rate for chronic exposure

Organ or tissue	Equivalent dose rate ($Sv.a^{-1}$)
Gonads	0.2
Lens of the eye	0.1
	0.4

Intervention levels in emergency exposure situations are expressed in terms of avertable dose, i.e. a protective action is indicated if the dose that can be averted is greater than the corresponding intervention level. The standards provide the values which can be taken as starting points for the judgement required for decisions to select levels for emergency exposure situations. These values have been developed by IAEA and summarized in Table 3.

Table 3. Recommended generic intervention levels for urgent protective measures

Protective action	Generic intervention level (dose avertable by the protective action)
Sheltering	10 mSv in a period of no more than two days
Temporary evacuation	50 mSv in a period of no more than one week
Iodine prophylaxis	100 mSv (absorbed dose due to radioiodine) *)

*) For children WHO recommends 10mSv.

The recommended generic action levels for foodstuffs are presented in Table 4.

Table 4. Generic action levels for foodstuffs (Bq/kg)

Radionuclides	Food for general consumption (kBq/kg)		Milk and infant foods drinking water (kBq/kg)	
Cs-134, Cs-137, Ru-103,	1000		1000	
Ru-106, Sr-89	1000		1000	
I-131	1000		100	
Sr-90	100		100	
Am-241, Pu-238, Pu-239	10		1	

It is noted that levels given in Table 5 apply to situations where alternative food supplies are readily available. Where food supplies are scarce, higher levels can apply.

Table 4 is based on, and consistent with, the Codex Alimentarius Commission's guideline levels for radionuclides in food moving in international trade following accidental contamination, but it is limited to the nuclides usually considered relevant to emergency exposure situations.

The generic optimized intervention levels recommended for temporary relocation and permanent resettlement are given in Table 5.

Table 5. Recommended generic intervention levels for temporary relocation and permanent resettlement

Actions	Avertable dose
Initiating temporary relocation	30 mSv in a month
Terminating temporary relocation	10 mSv in a month
Permanent relocation	1 Sv in lifetime