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FUNCTIONAL REQUIREMENTS IN EMERGENCY PREPAREDNESS AND RESPONSE

COURSE BOOK

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ABBREVIATIONS

AEA	Atomic Energy Act
ALARA	As low as reasonably achievable
ANS	American Nuclear Society
ARR	Airborne release rate
BAT	Best Available Technology
BEIR	Committee on the Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences
BLM	Bureau of Land Management
Bq	Becquerel (measurement unit)
BSS	Basic Safety Standards
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cGy	Centigray (measurement unit)
Ci	Curie (measurement unit)
CP	Command post
cpm	Counts per minute (measurement unit)
CR	Control room
CRARM	Presidential/Congressional Commission on Risk Assessment and Risk Management
CWS	Community Water System
DCF	Dose Conversion Factor
DDREF	Dose and dose rate effectiveness factor
DHS	Department of Homeland Security
DIL	Derived Intervention Levels
DOC	Departmental Operations Center
DOE	Department of Energy
DP	Dose Parameter
DRL	Derived Response Level
EAL	Emergency Action Level
EAP	Emergency Action Plan
EMS	Emergency Management System
EOC	Emergency Operations Center
EOF	emergency operations facility
EP	emergency planning
EPA	Environmental Protection Agency
EPC	Emergency Preparedness Category
EPD	Extended Planning Distance
EPR	Emergency Preparedness and Response
EPREV	Emergency preparedness Review
EPZ	Emergency Planning Zone
ERC	emergency response centre
ERNET	IAEA Emergency Response Network GAL generic action level

FDA	Food and Drug Administration
FEMA	Federal Emergency Management Agency
FRC	Federal Radiation Council
FRMAC	Federal Radiological Monitoring and Assessment Center
FRPCC	Federal Radiological Preparedness Coordination Committee
GIL	generic intervention level
GSR	General Safety Requirement
Gy	Gray (measurement unit)
hr	Hour
IAP	incident action plan
IC	Incident Commander
ICP	incident command post
ICPD	Ingestion and Commodities Planning Distance
ICRP	International Commission on Radiation Protection
ICS	incident command system
IDLH	immediately dangerous to life or heath IND improvised nuclear device
IEC	Incident Emergency Centre
IMAT	Incident Management Assistance Teams
INES	International Nuclear Event Scale
LET	linear energy transfer
ITB	Iodine Thyroid Blocking
LPF	leak path factor
LWR	Light Water Reactor
MAC	Multiagency Coordination Group
NCA(A)	national competent authority – for an accident abroad
NCA(D)	national competent authority – for a domestic accident
NPP	nuclear power plant
NREP	national radiation emergency plan
NWP	national warning point
OIL	Operational Intervention Level
OSC	operation support centre
PAZ	Precautionary Action Zone
PIC	public information centre
QA	quality assurance
RANET	Response and Assistance Network
RBE	Relative Biological Effectiveness
TMI	Three Mile Island (USA)
UC	Unified Command
UCCS	Unified Command and Control System
UPZ	Urgent Protective Action Planning Zone
WHO	World Health Organization

Brief description of the course

The practical objectives of emergency response, as defined in safety requirements publications, are to:

− restore control over the situation;

− stop the development or mitigate the consequences on the spot;

− to prevent the occurrence of deterministic effects affecting the health of workers and the population;

− provide first aid and treat radiation injuries;

− to prevent, to the extent practicable, the occurrence of stochastic effects in the population;

− to prevent, to the extent practicable, the occurrence of non-radiological effects in individuals and in the population;

− to protect, to the extent practicable, property and the environment;

− to prepare, to the extent practicable, for the resumption of normal social and economic activities.

To achieve these goals, readiness requirements are applied as part of the planning and preparation process.

The main requirements for the organization of emergency management and operations, set out in the publication of the category of safety requirements, relate to:

Response

− performing emergency response at the site promptly and without prejudice to the continuous implementation of operational safety functions;

− effective off-site response management in coordination with on-site response;

− coordination of the response between all organizations carrying out the response;

− assessment of the information needed to make decisions about resource allocation throughout the emergency.

Preparedness

− for installations classified as threat category I, II or III, a clear definition of the transition from normal to emergency operation, including an indication of the responsibilities of persons on site;

− for installations classified as threat category I or II, measures to coordinate the response of all organizations conducting off-site response with on-site response;

− measures to integrate national and local responses with responses to routine emergencies;

− activities related to the command and control system, including measures related to:

- coordination of activities;

- development of strategies;
- dispute resolution;
- mechanisms for obtaining and evaluating information;

– for installations classified as threat category I or II, response coordination measures between organizations and responding jurisdictions that fall within the Precautionary Action Zone (PAZ) or the Urgent Protective Action Planning Zone (UPZ).

Based on the above, the course covers the most important response functions, starting with the detection of conditions for Radiological emergency situations and ending with a thorough analysis of emergency situations and emergency response. It discusses in detail the mechanisms that should be created for the effective implementation of these functions.

Learning objectives

Upon successful completion of this module, students should be able to:

– Identify and notify of a nuclear or radiation emergency;

– Activate emergency response;

– Identify measures to mitigate the consequences of a nuclear or radiation emergency;

– Apply mitigating measures in the event of a nuclear or radiation emergency;

– Distinguish between protective actions and other measures in the event of a nuclear and radiation emergency;

– Assess emergency conditions when responding to emergencies;

– Develop protective measures for personnel and rescuers in the event of a nuclear or radiation emergency;

– Identify aspects of medical response in the event of a nuclear or radiological emergency;

– Participate in public communication and provide instructions to the general public

– Know the INES rating system;

– Classify the types of radioactive waste, as well as the objects of their location and disposal;

– Identify and propose measures to mitigate non-radiological consequences;

– Know international aid agreements and the Response and Assistance Network (RANET);

– Identify and recommend stopping nuclear or radiation emergencies;

– Analyze emergency situations and response measures to them.

INTRODUCTION

In the case that an accident does happen, there must be adequate means of transportation to reach the site and trained personnel to work in challenging conditions.

Philippe Jamet, former Commissioner,
French Nuclear Safety Authority

Radiological emergencies, caused by various reasons, will be also in the future. Therefore all nations must have arrangements to response to these emergencies. Especially after the accident at the Chernobyl nuclear power plant in 1986 major progress was made internationally and nationally in management of response to and recovery from nuclear and radiological emergencies. Notwithstanding the broadly adequate provisions now in place in most countries and internationally, complacency would be misplaced and continuing vigilance remains important. Improvements, of a technical, organisational or political nature, are still needed in emergency management.

The Fukushima Daiichi nuclear accident reinforced the importance of having adequate national and international safety standards and guidelines in place so that nuclear power and technology remain safe and continue to provide reliable low carbon energy globally.

By recognizing the lessons learned from the 2011 accident, the IAEA has been revising its global safety standards to ensure that Member States continue to receive up-to-date guidance of high quality.

“The Fukushima Daiichi accident has left a very large footprint on nuclear safety thinking, which manifested itself in a distinct shift from the prevention of design basis accidents to the prevention of severe accidents and, should an accident occur, the practical elimination of its consequences,” said Greg Rzentkowski, Director of the IAEA`s Division of Nuclear Installation Safety.

The Fukushima accident put these issues on the forefront of political debate and public opinion will certainly increase the need for developing preparedness strategies for emergency response and recovery all over the world in the following years. Radiological emergency may come about not only through an accident but also through nuclear terrorism or other malicious acts with radioactive materials. Addressing these challenges requires that nations set up arrangements to secure their territory from malicious and illegal acts and to protect their citizens» health and welfare from harmful effects of radiation. Safety and security arrangements have common goals and the systems and measures used to achieve these goals need to be complementary. Therefore, a well-coordinated approach in nuclear safety and security is essential.

EMERGENCY RESPONSE OPERATIONS MANAGEMENT

Regulations and standards for emergency response operations management

Radiological emergency preparedness is intended to protect people from radiation originating from uncontrolled radioactive sources and radioactive material, rather than from radiation-producing machines. Commercial nuclear power reactors would not be potential threats to the health and safety of the public around them except for the radioactive properties of their fuel and the large inventory of radioactive materials that develop in their coolant systems. The accidents of concern are therefore ones that allow radioactive material to escape into the environment. The proper public health response to an accident is selected based on radiation exposure to the public and on its consequences.

This operational focus on radiation exposure consequences requires emergency planners and event responders to be familiar with radiological concepts, units, measurements, and terminol- ogy. This discussion of radiological concepts is intended as an introductory overview for readers unfamiliar with the radiological sciences. It is brief and necessarily omits a great amount of the technical detail not required to understand and implement public protection schemes. Many of the detailed health physics calculations are not discussed because most emergency planners do not require that level of health physics proficiency. Additional information about radiological concepts can be found in many introductory health physics textbooks. Readers can also find information on the websites of the Nuclear Regulatory Commission (www.nrc.gov), Environmental Protection Agency (www.epa.gov), Health Physics Society (www.hps.org), National Council on Radiation Protection and Measurement (http:/www.ncrponline.org), and Conference of Radiation Control Program Directors (www.crcpd.org).

Although there are many forms of radiation, four forms are of primary interest in radiation protection at commercial nuclear power plants, three of which could reach the public after a major accident. The radiations of interest are designated alpha (α), beta (β), and gamma (γ); alpha and beta are particulate radiations that carry an electric charge, whereas gamma radiation is an electro-magnetic wave that does not have a charge. The fourth radiation, neutron (η), is also a particle that does not carry an electric charge. An alpha particle consists of two protons bound to two neutrons (identical to a helium nucleus, at a +2 charge); alpha is a massive and heavy subatomic particle with a very short range, delivering a large amount of energy.

The characteristic range of a radioactive atom is one factor in establishing how hazardous it is to humans: Very short range is not an external hazard because its range is shorter than the thickness of dead skin, medium ranges can be hazardous to the skin and for a small depth below the skin but not to organs well inside the body, and the longer ranges are hazardous throughout the body because of their very high penetrating power.

At the atomic level, when radiation collides with a target atom it is either absorbed or scattered (i.e., bounces off). Absorption only occurs if the remaining energy corresponds to an open energy shell or excitation energy. If the incoming radiation does not have the correct amount of energy for absorption then it is scattered; the exact angle of scattering is determined by the angle of incidence, radiation energy, and electric charge. Each change in direction causes a loss of energy; in some cases of very large changes in angle, particulate radiation can also create a gamma as it turns. Incoming radiation is continuously losing energy through scattering interactions until it eventually gives up enough energy to allow absorption to occur. Charged particulate radiation also loses energy through the interaction of its electric charge with atoms along its path; this kind of interaction does not change the path or direction of the radiation because it is not close enough for the interacting atom to be a target. Radiation energy is measured in electron volts (eV); a more practical unit for radia- tion protection is the kiloelectron volt (keV), or 1000 electron volts; 1000 keV is a megaelectron volt (MeV). The radiations that are caused by nuclear processes have characteristic energies between 20 keV and approximately 3500 keV.

At the biological level, radiation injures people. This damage comes from direct impingement against cellular structures and from collateral chemical damage induced by the free radicals (charged molecules) in cellular fluids that are created by ionization along the radiation path. In radiation biology, no consensus has been reached with regard to how many radiation hit events a cell can survive. The amount of effective damage is a function of the radiation rate (interactions per unit time), the radia- tion type, the radiation energy, and the cell type.

The word exposure has two uses in radiation protection. In the more common, colloquial usage, you are exposed to radiation whenever you are close enough to a radiation source for the associated radiation to reach you. This usage simply denotes that radiation interactions are possible, without quantifying those interactions in any way. The term also has a more technical meaning related to the amount of energy that is available to be deposited in the body.* The unit of radiation exposure is the röntgen (R, also referred to as roentgen), which represents a specific quantity of ionization in air (note that this discussion uses traditional radiation units rather than SI [metric] units, because traditional units are mandated in the United States). The actual amount of energy absorbed by the body is referred to as the absorbed dose, measured in rads (ergs/gram tissue), which is essentially a calorimetric measurement. The quantity used most frequently in radiation protection is the rem, which reflects the amount of biological damage done by the absorbed dose. The precise value of the rem varies with the radiation type, the target organ, and other factors. One rad of alpha radiation results in the most rems (internal dose only, as the external skin dose will be zero), 1 rad of gamma radiation the fewest rem, and beta radiation intermediate between them.

In terms of biological damage, roentgens, rads, and rems are large units and represent a significant exposure and dose. The working units are typically the milliroentgen (mR, or more commonly mR/h expressed as a rate) and mrem. In each case, milli indicates 1000th, or 0.001 times. It should be noted that the roentgen is only defined for gamma radiation. Portable radiation survey instruments are typically calibrated to measure mR/h for gamma radiation over a specific energy range in keV. Radiation protection personnel typically treat mR and mrem as interchangeable and often refer to mR/h as the dose rate, when it is the exposure rate. This is because for gamma radiation 1 R produces 0.96 rem, which is rounded up to 1. For purely external exposure this imprecise use of units does not have any practical effect.

In general, two categories of radiological measurements are made:

1) radiation exposure and

2) the number of decays.

Radiation originating from radioactive material taken inside the body is referred to as internal radiation. The most important intake route for members of the public during a radiation accident is through the lungs (breathing) and, to a much lesser extent, the digestive system (stomach and intestines) from radioactive material in the food chain. Radioactive material can also be absorbed through the skin or through open wounds, but these modes are more likely to be a concern in protecting emergency workers rather than for the general public. The amount of radioactive material initially taken into the body depends primarily on its solubility in blood, and the distribution of radioactive material inside the body depends on the affinity of organs for the chemical form of the radioactive material. When radioactive material enters the body, it decays radiologically and is eliminated biologically through excretion processes. These are separate elimination processes that proceed in parallel, resulting in a total elimination time that is faster than either one by itself. Each combination of organ and radioactive material has a characteristic elimination rate that follows the same mathematics as radiological decay. Biological elimination is usually described by the biological half-life, which is completely governed by the element, not by the isotope. The combination of radioactive and biological decay results is described by the effective half-life, a quantity that is shorter than either the biological or radiological half-lives alone. For large organs, internal radiation has the greatest dose effect on the organ in which the material collects, whereas for small organs the greatest effect is on nearby organs.

For emergency preparedness purposes, the most important organ-level effects of radiation on the human body are direct radiation injury and an increase in an individual»s likelihood of experiencing a variety of cancers (the overall risk of cancer for men is about 45% and for women 38%).

Radiation injury can include reddening and blistering of the skin, cataract formation on the eyes, suppression of red blood cell formation, damage to the intestinal tract leading to bacterial infections in the bloodstream, and, in extreme cases, the direct killing of essential nerve cells. The appearance of a radiogenic cancer is delayed from the initiating cellular damage, with each type of cancer having a characteristic delay period ranging from 3 years to roughly 40 years; for example, leukemia is the earliest occurring of the radiogenic cancers, typically appearing 3 to 5 years after the precursor radiation damage. It is worth noting that not all cancers, even in persons with occupational or accidental exposure to radiation, are radiogenic in origin. Some cancers are more likely to be radiogenic than others, and for any single individual cancer it is generally impossible to prove a definitive cause.

The dose equivalent to individual organs is calculated by multiplying the activity (in μCi) resi- dent in the organ by a dose conversion factor that depends on the length of the exposure period. The usual practice is to calculate the dose that an organ receives for 50 years after the depositing of radioactive material in the organ and then assign that entire dose to the year in which the intake occurs. In practice, most radioactive materials are not resident in the body for 50 years, and the exceptions are not typically released in power reactor accidents. A dose equivalent calculated for 50 years of exposure is referred to as the committed dose equivalent (CDE). Tables of CDE dose conversion values can be found in standard dosimetry references (e.g., USEPA, 1988, 1993).

The most important means of protection against radiation dose are time, distance, and shielding. Dose is reduced or prevented by spending as little time in a radiation field as possible. Dose is reduced by staying as far away from a radioactive source as possible. Dose is also reduced by placing absorbing materials (shielding) between the radiation source and the at-risk individual.

The central principle of radiation protection is expressed in the acronym ALARA, which refers to "as low as reasonably achievable" radiation doses. This principle applies to accident or emergency situations as well as routine operations and underlies radiation protection for the public as well as for emergency workers.

An important working assumption in radiation protection is that any dose of radiation has a potential to increase an individual»s risk of cancer, with progressively greater risk with greater dose. This has been shown to be true for chronic exposures of 50 rem or more and is extrapolated to lower total doses where the effect has not been clearly demonstrated. This model, the linear no-threshold model, is the basis for regulatory radiation dose limits. The actual risks of cancer for individuals chronically exposed to low (less than 10 rem) radiation doses remains unknown and may remain unknowable because of the very large populations needed to settle the question with statistical certainty.

Radiation doses delivered in a single event over a short period, such as a few hours or less, are described as acute exposures, whereas exposures that continue over an extended time, such as weeks, months, or years, are described as chronic. Discernible changes in human cells have never been observed for acute doses of less than approximately 10 rem. The range of doses less than 5 rem (5000 mrem) can be described as being in the regulatory range because 5 rem dose equivalent is the regulatory annual limit for occupational exposure. The range of 5 to 25 rem can be described as the extraregulatory range because doses in this range can be permitted under some (rare) circumstances. Cellular level changes can be observed from radiation doses in the range between 10 and 100 rem, but no acute radiation injury occurs even in radiosensitive individuals. In the range of 100 to 250 rem, radiation injury occurs with the initial effects being suppression of new red blood formation and damage to the cells lining the intestines. Acute radiation doses of 250 rem or greater could be fatal to the most radiosensitive individuals, and damage to red blood cell-producing marrow and the intestines becomes progressively greater with dose, until 50% of individuals exposed to 450 to 500 rem do not survive 30 days following exposure without extensive medical treatment. When modern medical treatment is available, 50% of individuals acutely exposed to approximately 500 to 600 rem survive at least 30 days. Individuals who do not survive radiation exposure at these doses most commonly die from a combination of anemia (a lack of red blood cells and depressed oxygen transport in the blood) and bloodborne infections resulting from destruction of the protective barrier of cells in the intestines complicated by suppression of the immune system. As dose continues to rise, nerve cells and more other radiation-resistant cells begin to be killed; doses near 1000 rem are generally not survivable regardless of medical treatment.

Following the accident, through a review of relevant standards, including the IAEA safety standard on design safety, experts found that a higher level of safety could be incorporated into existing nuclear power plants by adhering to more demanding requirements for protection against external natural hazards and by enhancing the independence of safety levels so that, even if one layer fails, another layer is unimpacted and stops an accident from happening.

While requirements for protection against natural hazards have always been included in the design of nuclear reactors, these have been strengthened since the accident. In general, the design requirements now take into account natural hazards of an estimated frequency above 1 in 10 000 years, as opposed to 1 in 1000 years used previously.

The independence of reactor levels in the defence in depth concept, which ensures that the various levels of defence in a plant act as independently as possible and thereby provide for effective implementation of safety functions, was also strengthened. The need for this independence can particularly be seen in the protection of reactors against common cause events. For example, in the case of a tsunami, back-up safety systems should be located at an elevation sufficiently high to be protected from potential flooding and ensure their operability when systems designed for normal operation have failed.

Implementing improved safety measures

Incorporating these new safety standards into the design of existing reactors was subsequently tested through comprehensive safety assessments and inspections. The assessments took into account the design features of installations, safety upgrades and provisions for the use of non-permanent equipment to demonstrate that the probability of conditions that may lead to early or large releases is practically eliminated.

"New power plants are designed to account for the possibility of severe accidents," said Javier Yllera, a senior Nuclear Safety Officer at the IAEA. "Different safety improvements have been implemented at existing power plants, together with accident management measures."

Safety assessments or «stress tests» implemented in the European Union following the Fukushima Daiichi nuclear accident focused on the assessment of natural hazards such as earthquakes and flooding, and on the behaviour of power plants in cases of extreme natural events and severe accidents. The overall objective was to analyse the robustness of reactors to such events and, if necessary, increase it. The margins of the safety of reactors were analysed and possible improvements were identified. The implementation of those stress tests remained the responsibility of Member States, and resulted in many design and operation enhancements in Europe.

As an example, the French Nuclear Safety Authority (ASN) initiated an assessment of the country»s 56 nuclear power reactors as well as the 2 EPR reactors under construction. The ASN then prescribed the implementation of both fixed and mobile equipment that could potentially prevent a large release, including high-resistance diesel generators and pumps able to function in extreme scenarios such as major earthquakes or flooding. The availability of alternative sources of water for cooling was also prescribed under the same conditions. In addition, the ASN required a back-up plan including rapid action force groups that can be on site within 24 hours with light equipment and within three days with heavy equipment, using transportation means such as helicopters, and that can operate in a severely disrupted environment.

"One of the lessons learned from the Fukushima Daiichi accident is that disruptions caused on and off site by extreme natural hazards can pose major problems," said Philippe Jamet, former Commissioner of the ASN and Chairman of the Board of the European stress tests. "In the case that an accident does happen, there must be adequate means of transportation to reach the site and trained personnel to work in challenging conditions."

An international framework facilitates the development and maintenance of capabilities and arrangements for preparedness and response to nuclear and radiological incidents and emergencies. The IAEA and the Inter-Agency Committee on Radiological and Nuclear Emergencies are the prime interagency coordination mechanism in emergency preparedness and response.

Legal instruments

The Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency are the main legal instruments on emergency preparedness and response and form the legal basis for the international EPR framework. They place specific obligations on the States Parties and the IAEA.

Safety Standards and technical guidance

The IAEA Safety Standards dealing with emergency preparedness and response, along with a range of technical guidance documents and tools, provide requirements, recommendations, guidelines and good practices for building a sound level of emergency preparedness and effective emergency response.

International operational arrangements

These arrangements are the practical means by which the IAEA, its Member States and other international organizations maintain emergency preparedness and effectively respond to any nuclear and radiological incident or emergency.

During normal operations and particularly in the event of the unexpected, an adequate legal framework for the safe, secure and peaceful use of nuclear technology is indispensable. The national and international nuclear legal systems of today provide a legal framework for conducting activities related to nuclear energy and ionizing radiation in a manner that adequately protects individuals, property and the environment, and helps determine liability when something goes wrong.

The 1986 Chornobyl accident prompted the swift adoption of the Convention on Early Notification of a Nuclear Accident (Early Notification Convention) and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Assistance Convention), which form the legal basis for the international emergency preparedness and response framework. Further negotiations led to the adoption of the Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention in 1988, as well as the Protocol to Amend the Vienna Convention on Civil Liability for Nuclear Damage and the Convention on Supplementary Compensation for Nuclear Damage in 1997. In addition, the 2011 Fukushima Daiichi nuclear accident catalyzed efforts to further strengthen the existing framework for nuclear liability and safety.

“At the time of the Chornobyl accident in 1986, there were few treaties that had been concluded under the auspices of the IAEA in relation to the peaceful uses of nuclear energy,” said Andrea Gioia, Senior Legal Officer at the IAEA. In addition to the adoption of the 1986 Early Notification and Assistance Conventions, the Convention on Nuclear Safety (CNS) was later adopted in 1994, followed by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management in 1997.

Following the Fukushima Daiichi nuclear accident, Member States adopted the IAEA Action Plan on Nuclear Safety, in which one of the 12 areas outlined focused on reinforcing the international legal framework. “The main emphasis here was placed on the effective implementation of the existing treaties, as well as on the strengthening of the nuclear liability regime,” Gioia said.

Facilitating global nuclear liability

The significance of a global nuclear liability regime to delineate legal responsibilities “lies in two major areas: public confidence and nuclear trade. If nuclear power is to play its necessary part in the decarbonization of world energy supply, it is critical that barriers to the development of new facilities, such as uncertainty around liability arrangements, are removed,” said Steven McIntosh, Chairman of the International Expert Group on Nuclear Liability (INLEX).

The IAEA Action Plan sets out the need to establish “a global nuclear liability regime that addresses the concerns of all States that might be affected by a nuclear accident, with a view to providing appropriate and sufficient compensation for nuclear damage," McIntosh, who is also Senior Manager of Government and International Affairs at the Australian Nuclear Science and Technology Organisation (ANSTO), said.

Though the Convention on Supplementary Compensation for Nuclear Damage (CSC) was adopted in 1997, it was not until 2015 that it entered into force when Japan submitted its instrument of acceptance.

"Contracting Parties have decided to create a system of regular meetings to examine problems of common interest and to further promote adherence to the CSC, strengthening global liability," Gioia said.

The first meeting of the CSC parties took place in 2018, and the next meeting is expected to convene in August 2021 in Vienna. The CSC aims to increase the amount of compensation available in the event of a nuclear accident through public funds to be made available by the Contracting Parties at the United Nations rate of assessment.

Upholding the Convention on Nuclear Safety

While attempts to amend the CNS following the Fukushima Daiichi accident were unsuccessful, a political declaration — the Vienna Declaration on Nuclear Safety (VDNS) — was adopted by consensus in 2015. The VDNS guides Contracting Parties in the design, siting and construction of new nuclear power plants and contains guidance on periodic safety assessments of existing installations to identify safety improvements to meet CNS objectives. "Contracting Parties also committed themselves to reflect these principles in their actions when preparing their Reports to be submitted for consideration of the 7th Review Meeting of the CNS in 2017," said Judit Silye, IAEA Legal Officer.

Furthermore, the Working Group on Effectiveness and Transparency was established to provide guidance on meeting CNS objectives, as well as to support the preparation of National Reports and improve transparency, the review process and international cooperation. "In this regard, each National Report is made publicly available after the Review Meeting, unless the Contracting Party concerned notifies the Secretariat otherwise," Silye added.

Convention on Nuclear Safety

One of the objectives of the Convention on Nuclear Safety (CNS), which entered into force on 24 October 1996, is "to achieve and maintain a high level of nuclear safety worldwide through the enhancement of national measures and international cooperation." The obligations for the 90 Contracting Parties under the CNS include submitting National Reports on the implementation of their obligations under the CNS for "peer review" in meetings held every three years.

Conventions, treaties and agreements

- Convention on Early Notification of a Nuclear Accident
- Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency
- Convention on Nuclear Safety
- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
- Convention on the Physical Protection of Nuclear Material (CPPNM)
- Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage
- Code of conduct on the safety of research reactors
- Treaty on the Non-Proliferation of Nuclear Weapons (NPT)
- Treaty for the Prohibition of Nuclear Weapons in Latin America (Tlatelolco Treaty)
- African Nuclear-Weapon-Free ZoneTreaty (Pelindaba Treaty) (including Annexes and Protocols) and Cairo Declaration
- South Pacific Nuclear Free Zone Treaty (Rarotonga Treaty) (and Protocols)
- Southeast Asia Nuclear Weapon-Free Zone Treaty (Treaty of Bangkok)

- Agreement between the Republic of Argentina, the Federative Republic of Brazil, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) and the IAEA for the Application of Safeguards
- Verification Agreement between the IAEA and the European Atomic Energy Community (EURATOM)
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)
- International Convention for the Safety of Life at Sea (SOLAS)
- Convention Relating to Civil Liability in the Field of Maritime Carriage of Nuclear Material (NUCLEAR)
- Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space and Under Water
- Paris Convention on Third Party Liability in the Field of Nuclear Energy
- Brussels Convention Supplementary to the Paris Convention

International operational arrangements

These arrangements are the practical means by which the IAEA, its Member States and other international organizations maintain emergency preparedness and effectively respond to any nuclear and radiological incident or emergency.

The international operational arrangements comprise the Operations Manual for Incident and Emergency Communication (IEComm), the IAEA Response and Assistance Network (RANET) and the Joint Radiation Emergency Management Plan of the International Organizations (JPLAN).

IEComm facilitates the implementation of the articles of the Early Notification Convention and the Assistance Convention that are operational in nature, such as the provisions for notification and information exchange and the communication protocols for Contact Points identified under the Early Notification Convention and the Assistance Convention (through messages via faxes, telephone lines, emails and a secure and protected web site that could be responded to around the clock). These measures are the subject of regular exercises of various levels of complexity called convention exercises (ConvEx).

RANET was established to facilitate the provision of international assistance upon request and in compliance with the Assistance Convention. This system forms an operational mechanism to provide assistance in different technical areas, with the help of national capabilities registered in the network.

JPLAN describes a common understanding of how each organization acts during a response and in making preparedness arrangements for a nuclear or radiological emergency. It provides a mechanism for coordination, and clarifies the roles and capabilities of the participating international organizations. It is maintained by the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE), for which the IAEA provides the Secretariat.

IAEA Safety standards on emergency preparedness and response

The IAEA Safety Standards dealing with emergency preparedness and response (EPR), along with a range of technical guidance documents and tools, provide requirements, recommendations, guidelines and good practices for building a sound level of emergency preparedness and effective emergency response.

One of the IAEA`s statutory functions is to establish or adopt standards of safety to protect public life, health and property. Under the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, one of the Agency»s functions is to collect and disseminate to States Parties and Member States information concerning methodologies, techniques and available research results that relate to the response to such emergencies. The IAEA fulfils these functions in part through the publication of safety standards, technical guidelines and tools in EPR.

The IAEA Safety Standards are not legally binding on Member States but may be adopted by them, at their own discretion, for use in national regulations in respect of their own activities. The Standards are, however, binding on the IAEA in relation to its own operations and on States in relation to operations assisted by the IAEA.

The IAEA Safety Requirements establish the conditions that must be met to ensure the protection of people and the environment. The Agency`s Safety Guides provide recommendations and guidance on how to comply with the Safety Requirements and indicate an international consensus on the recommended measures.

Fig 1. The main elements that need to be established for the framework for Emergency preparedness and response

Let's look further at the main regulatory guidelines of Emergency preparedness and response

Safety Fundamentals

IAEA Safety Standards Series No. SF-1 Fundamental Safety Principles

General Safety Standards

Safety Requirements

IAEA Safety Standards Series No. GSR Part 1 (Rev.1) Governmental, Legal and Regulatory Framework for Safety

IAEA Safety Standards Series No. GSR Part 2 Leadership and Management for Safety

IAEA Safety Standards Series No. GSR Part 3 Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards

IAEA Safety Standards Series No. GSR Part 4 (Rev.1) Safety Assessment for Facilities and Activities

IAEA Safety Standards Series No. GSR Part 5 Predisposal Management of Radioactive Waste

IAEA Safety Standards Series No. GSR Part 6 Decommissioning of Facilities

IAEA Safety Standards Series No. GSR Part 7 Preparedness and Response for a Nuclear or Radiological Emergency

Safety Guides

IAEA Safety Standards Series No. GSG-1 Classification of Radioactive Waste

IAEA Safety Standards Series No. GSG-2 Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency

IAEA Safety Standards Series No. GS-G-2.1 Arrangements for Preparedness for a Nuclear or Radiological Emergency
IAEA Safety Standards Series No. GS-G-3.1 Application of the Management System for Facilities and Activities
IAEA Safety Standards Series No. GSG-7 Occupational Radiation Protection
IAEA Safety Standards Series No. GSG-8 Radiation Protection of the Public and the Environment
IAEA Safety Standards Series No. GSG-11 Arrangements for the Termination of a Nuclear or Radiological Emergency
And other

Specific Safety Standards

Nuclear Power Plants
Safety Requirements
IAEA Safety Standards Series No. SSR-2/1 (Rev.1) Safety of Nuclear Power Plants: Design
IAEA Safety Standards Series No. SSR-2/2 (Rev.1) Safety of Nuclear Power Plants: Commissioning and Operation
IAEA Safety Standards Series No. NS-R-3 (Rev.1) Site Evaluation for Nuclear Installations
Safety Guides
IAEA Safety Standards Series No. GS-G-3.5 The Management System for Nuclear Installations
IAEA Safety Standards Series No. GS-G-4.1 Format and Content of the Safety Analysis Report for Nuclear Power Plants
And other

Research Reactors
Safety Requirements
………
Safety Guides
………
Fuel Cycle Facilities
Safety Requirements
………
Safety Guides
………
Radioactive Waste Disposal Facilities
Safety Requirements
………
Safety Guides
………
Mining and Processing
Safety Guide
IAEA Safety Standards Series No. WS-G-1.2 Management of Radioactive Waste from the Mining and Milling of Ores

Application of Radiation Sources
Safety Guides
………
Transport of Radioactive Material
Safety Requirements
………
Safety Guides
………

With a view to ensuring the protection of people and the environment from harmful effects of ionizing radiation, the IAEA safety standards establish fundamental safety principles, requirements and measures to control the radiation exposure of people and the release of radioactive material to the environment, to restrict the likelihood of events that might lead to a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation, and to mitigate the consequences of such events if they were to occur. The standards apply to facilities and activities that give rise to radiation risks, including nuclear installations, the use of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

Safety measures and security measures have in common the aim of protecting human life and health and the environment. Safety measures and security measures must be designed and implemented in an integrated manner so that security measures do not compromise safety and safety measures do not compromise security.

The IAEA safety standards reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation. They are issued in the IAEA Safety Standards Series, which has three categories.

Safety Fundamentals

Safety Fundamentals present the fundamental safety objective and principles of protection and safety, and provide the basis for the safety requirements.

Safety Requirements

An integrated and consistent set of Safety Requirements establishes the requirements that must be met to ensure the protection of people and the environment, both now and in the future. The requirements are governed by the objective and principles of the Safety Fundamentals. If the requirements are not met, measures must be taken to reach or restore the required level of safety. The format and style of the requirements facilitate their use for the establishment, in a harmonized manner, of a national regulatory framework. Requirements, including numbered «overarching» requirements, are expressed as «shall» statements. Many requirements are not addressed to a specific party, the implication being that the appropriate parties are responsible for fulfilling them.

Safety Guides

Safety Guides provide recommendations and guidance on how to comply with the safety requirements, indicating an international consensus that it is necessary to take the measures recommended (or equivalent alternative measures). The Safety Guides present international good practices, and increasingly they reflect best practices, to help users striving to achieve high levels of safety. The recommendations provided in Safety Guides are expressed as «should» statements.

The Safety Standards Series No. SF-1 states the fundamental safety objective and ten associated safety principles, and briefly describes their intent and purpose. The fundamental safety objective — to protect people and the environment from harmful effects of ionizing radiation — applies to all circumstances that give rise to radiation risks. The safety principles are applicable, as relevant, throughout the entire lifetime of all facilities and activities — existing and new — utilized for peaceful purposes, and to protective actions to reduce existing radiation risks. They provide the basis for requirements and measures for the protection of people and the environment against radiation risks and for the safety of facilities and activities that give rise to radiation risks, including, in particular, nuclear installations and uses of radiation and radioactive sources, the transport of radioactive material and the management of radioactive waste.

The objectives of emergency response are to:

a) Prevent deterministic health effects (deaths and injuries) by: Taking action before or shortly after a major (core damage) release or exposure from a reactor accident Keeping the public and emergency worker doses below the thresholds for deterministic health effects.

b) Reduce the risk of stochastic effects on health (primarily cancer and severe hereditary effects) by: Implementing protective actions in accordance with IAEA guidance.

Deterministic health effects can be prevented by taking protective actions before or shortly after a release. These immediate actions must be based on plant conditions and then refined subsequently based on environmental measurements. The risk of stochastic health effects is reduced by taking actions based on ambient dose rates and analysis of environmental samples. Sampling and analysis are performed to evaluate the safety of food, milk, and water in areas where ambient dose rates or deposition concentrations indicate that restrictions may be warranted. Sample analysis is also used to refine the operational intervention levels (OELs) used to interpret environmental measurements

Implementing protective measures early in an accident should not be delayed by meetings, detailed calculations or other time consuming activities. In addition severe accidents are not well understood and early in an accident there will be only limited reliable information on which to make decisions. Therefore the basic philosophy of this manual is to keep the process simple, yet effective. The manuals provides criteria that are:

a) predetermined, allowing for immediate actions to be taken,
b) measurable by the instruments used,
c) very simple, yet effective and
d) based on our best understanding of severe accidents and international guidance.

Plant conditions are assessed using control room instrument readings and other observable information to determine the risk and characteristics of a potential release. Environmental data are assessed primarily through the use of operational intervention levels (OIL), which are quantities directly measured by the field instruments. Default OILs have been calculated in advance on the basis of the characteristics of severe reactor accidents. These default OILs are used to assess environmental data and take protective actions until sufficient environmental samples are taken and analysed to provide a basis for their revision. This approach allows data to be quickly evaluated, and decisions on protective actions to be promptly made.

There are several types of events that could result in dispersion of radioactive substances into the environment. These include both intentional and unintentional events. Releases of radioactive substances could range from major accidents at nuclear facilities or explosion of a nuclear weapon to small events such as a transportation accident.

The extent of the contamination and radiological impact on the environment and people depend greatly on the type of an event and the radionuclides involved. However, many aspects of responding to the situation and of protecting people will be similar regardless of the spatial scale and involved radionuclides.

The first goal in a radiological or nuclear emergency is to protect the affected people. From radiation protection point of view this means striving to avoid all deterministic (harmful tissue reactions) health effects of radiation and to minimize the appearance of stochastic health effects in the affected population to a level which is practically achievable. There will be also other health effects which are related with people»s worry and anxiety about their own and relatives» health. These psychological impacts might need more attention than the radiological health impacts.

The planning and implementation of protective actions in a case of nuclear or radiological emergency is co- operation of several authorities and expert organisations. Composition of the groups planning decisions on countermeasures depends on the type of an emergency and also on the phase of the situation. There are several potential pathways of people»s exposure to radiation in a radiological emergency situation. In the early phase of an emergency people can be exposed to external radiation from the contaminated air and to internal radiation from inhaled radionuclides. Soon after, different surfaces in the environment and the ground will be contaminated and people will be exposed to external radiation from deposited radionuclides. Later on, the local foodstuffs and drinking water might be contaminated and people will be exposed to internal radiation from ingested radionuclides.

For example in a case of a severe nuclear power plant accident, there is always a certain time before any radioactive releases to the environment take place. In this threat phase, decisions are normally made by the operator and the local rescue officers, and the decisions are based on «best estimates» about the development of the plant condition. In later phases of the accident also other organisations will be involved in decision making and planning of countermeasures and protective actions. Also the grounds on which the decisions are based will change when more information about the accident and the radiological situation in the environment is available.

The past six decades have shown that various accidents with the use of radioactive and nuclear materials must be taken into consideration although today the likelihood of major accidents is small and releases of radioactive substances into the environment are minimized with effective safety and security systems. As the consequence of the terrorist attacks during the past few years, political leaders and authorities have become more aware of a need to re-assess existing threats and our preparedness to them. There are several lessons learned from the recent attacks and other events where radioactive or nuclear materials have been involved. Terrorists» intent to stage multiple events simultaneously must be taken into account in emergency planning today. Suicide scenarios and the fact that terrorists deliberately choose improbable or unexpected events lead to the conclusion that we can no longer rely on historical factors such as the probability of failure rates of various components to predict the likelihood of an event. One lesson is also to realize that multiple hazardous agents may be combined in an attack. Thus, planning for a radiological incident alone is an outmoded concept and authorities need to be able to recognise and respond to a situation where there is a combined chemical, biological, and radiological/nuclear hazard (CBRN).

There are more than 400 commercial nuclear power reactors, 10-20 reprocessing plants, almost 300 nuclear research reactors and more than 200 nuclear powered ships and submarines in operation around the world. Most of these facilities are situated quite close to residential areas and accidents happened with them might have severe consequences to the local population. Hundreds of accidents and incidents have occurred with small research reactors and nuclear powered ships and submarines. Some of them have resulted in loss of lives and human exposure to radiation at different levels. Accidents at nuclear submarines and vessels may lead to serious consequences to population only if they happen at harbours. Damaged reactor of a nuclear submarine and vessel may result in dispersion of radioactive materials within an area of few tens of square kilometres calling for protective actions, and later on also clean-up actions. Small research rectors are normally close to or inside inhabited areas and their severe accidents may also contaminate areas of few tens of square kilometres and protective and clean-up actions might be needed.

Few severe accidents have happened with nuclear power reactors, the most well known at the Fukushima Daiichi plant in Japan in 2011, the Chernobyl plant in Ukraine in 1986, the Three Mile Island plant in Pennsylvania in USA in 1979, and the Windscale plant in Cumbria in Northern England in 1957.

Highly radioactive sources are used for a variety of purposes, such as medicine, research, industry, and instrument calibration. Experience worldwide shows that, despite the existence of a regulatory framework, control of such high-active sources may nevertheless be lost, even in countries with rigorous regulatory systems. A large number of incidents involving the loss of control have been reported over the last 50 years. Following the terrorist attacks during the past few years, there have been heightened concerns about terrorist activity on, inter alia, radioactive sources, and level of control and regulation has been raised. For example in the European Union, the member states have implemented control of high-active sealed radioactive sources and orphan sources in their national legislation, based on the directive on high-active sealed sources and orphan sources of the Council of the European Union in 2003.

International harmonisation of criteria

The International Commission on Radiological Protection (ICRP) revised its basic recommendations for a system of radiological protection in its Publication 103. The previous process-based protection approach using practices and interventions was replaced with an approach based on exposure situations, i.e. planned, emergency and existing situations. The fundamental principles of justification and optimisation of protection are applied to all controllable exposure situations. Application of the Commission»s recommendations for the protection of people in emergency and post-emergency existing exposure situations were later described in the ICRP Publications 109 and 111, respectively.

The reference level, introduced by the ICRP, is a level of residual dose or risk above which it is generally judged not to be appropriate to plan to allow exposures to occur. Therefore, any planned protection strategy should at least aim to reduce exposures below this level, with optimisation achieving still lower exposures. Protection against all exposures, above or below the reference level, should be optimised. In the context of developing response plans for emergency exposure situations, the ICRP recommends that national authorities should set reference levels between 20 mSv and 100 mSv effective dose (acute or per year, as applicable to the emergency exposure situation under consideration). Reference levels below 20 mSv may be appropriate for the response to situations involving low projected exposures. There may also be situations where it is not possible to plan to keep all doses below the appropriate reference level, e.g. extreme malicious events or low-probability, high-consequence accidents in which extremely high acute doses can be received within minutes or hours. For these situations, it is not possible to plan to avoid such exposures entirely, and therefore, the ICRP advises that measures should be taken to reduce the probability of their occurrence, and response plans should be developed that can mitigate the health consequences where practicable. The best possible protection will be achieved by considering simultaneously all exposure pathways and all relevant protection options when deciding on the optimum course of action. Each individual protective measure must be justified by itself in the context of an overall protection strategy, but also the full protection strategy must be justified.

In addition to the reference level, the ICRP recommends to set, in advance, internally consistent dose criteria for protective actions that need to be taken promptly in order to be effective, and, based on these criteria, to derive appropriate triggers, expressed as readily measurable quantities, for initiating them in the event of an emergency.

The basic principles of radiation protection and the recommended criteria issued by the ICRP have been implemented in the international Basic Safety Standards (BSS) and adopted also in directives of the European Union. The international BSS and the European BSS are at the moment under revision based on the latest ICRP recommendations. These basic safety standards and the ICRP recommendations lay down the bases for international harmonisation of criteria and actions taken in a radiological emergency. National authorities in several countries are at the moment setting their national criteria to be applied in radiological emergencies. Because the reference levels are not directly measurable quantities, operational criteria will also be needed.

Soon after the Chernobyl accident in 1986, some international criteria were set. For example concerning foodstuff contamination, the European Council set regulations on maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a radiological emergency. These levels are shown in Table 1.

Due to Chernobyl accident, the European Council issued in 1990 the regulation concerning import of agricultural products originating in third countries. The recommended maximum concentrations of ^{134}Cs and ^{137}Cs together for dairy products and baby food is 370 Bq/kg and for other foodstuffs 600 Bq/kg. In 2003, the European Commission issued the recommendation, that natural products (game meat, mushrooms and fish) in internal trade of the EU shall not exceed the sum concentration of ^{134}Cs and ^{137}Cs of 600 Bq/kg.

Table 1

Maximum permitted levels of radionuclides in various foodstuffs and drinking water in the European Union

Radionuclides[1]	Activity concentration, Bq/kg		
	Baby food	Dairy products and liquid foodstuffs[2]	Other foodstuffs[3]
Strontium isotopes in total	75	125	750
Iodine isotopes in total	150	500	2 000
Plutonium and transplutonium isotopes in total	1	20	80
Other radionuclides in total[4], with half-life over 10 days, e.g. ^{134}Cs and ^{137}Cs	400	1 000	1 250

1.Activity levels for different groups of radionuclides are not dependent on each other. Each level is applied separately.
2.Concerns also drinking water.
3.For some, not frequently used, foodstuffs, e.g. certain spices, the activity levels to be enacted are ten times higher than the values in this table for basic foodstuffs.
4.Does not concern H-14 (carbon), K-40 (potassium) and tritium

These levels are still valid in the EU. The activity levels due to Chernobyl accident are disabled if the activity levels of Table 1 are put into force due to a new nuclear or radiological emergency.

The international trade of foodstuffs follows recommendations of the Codex Alimentarius standard. The aim of Codex Alimentarius is that annual effective dose from foodstuffs is below 1 milliSv. Codex Alimentarius limit values are not lowered in the later years either because it is assumed that the amount of contaminated products in international trade is decreased due to, among others, market mechanism and measures to decrease the activity concentrations in foodstuffs.

Striving to achieve consistency between the decisions and actions taken at national levels in an emergency is the most advisable because divergent national decisions on protective actions would cause unnecessary confusion and concern among the population. The accident at the Fukushima Daiichi nuclear power plant is a good example of diverging decisions taken by foreign authorities protecting their citizens in Japan, e.g. regarding evacuation of foreign citizens in Japan, iodine prophylaxis of foreign citizens in Japan, and monitoring of passengers returning home from Japan.

There are plenty of actions which can be taken to protect people in a radiological emergency. Of course, actions to be taken depend on the type and scale of the radiation situation and also the feasibility of actions. The feasibility in turn, is dependent on many factors, such as the time being available for the action, phase of an emergency situation, resources being available, etc. The list below contains some protective actions, which will be weighed if significant amount of radioactive substances are dispersed into the environment:

- sheltering indoors (partial sheltering, lifting the sheltering)
- iodine prophylaxis (children, adults)
- evacuation of people (before or after the contamination of the environment)
- control of access to contaminated areas
- temporary relocation of people
- permanent relocation of people
- clean-up of the environment (grass cutting, soil removal, ploughing, fire-shooting, vacuum sweeping, road planing, tree removal, cleaning interiors, sandblasting buildings, high pressure hosing, etc.)

- decontamination of people (self-decontamination, controlled decontamination)
- treatment of contaminated people in hospitals
- actions on foodstuffs, feedingstuffs and drinking water (use restrictions, prohibition of use, etc.)
- actions concerning livestock production, other raw materials and production facilities
- handling of radioactive waste
- etc.
- no actions

It goes without saying that people who participate in decision making of these protective measures represent various population groups and authorities. For example in the exercises in seven European countries focusing on clean-up actions of inhabited areas after a nuclear accident, the decision making panels represented the following fields of activities:

- Ministries of interior, public health, environment, economy, defence
- Provincial governments
- Affected cities
- Environmental protection and management
- Waste management
- Consumer services
- Police
- Rescue services
- Nuclear power companies
- Radiation protection authorities
- Nuclear safety authorities
- Health authorities
- Defence forces
- Food control
- Local government and agencies

All partners and stakeholders participating in the decision making will bring their own values to the decision making process, and weighing these values against each other is not an easy task. Therefore it is recommended to use formal decision analyzing tools in decision making panels. Today there are several computer based decision analyzing tools available and these tools make decision making transparent. Transparency is a key issue in decision making, because decisions on protective actions will affect every person»s normal life in the affected area.

Especially in the late and recovery phases of a radiological emergency, when there is time enough to arrange decision making meetings, the use of decision analyzing tools is important to make the process transparent. All participants in the decision making leave their fingerprint in the process and afterwards it is possible to figure out the values they presented and how theses values were weighed against each other. The values can vary from side to side, but normally they can be grouped in the following categories:

- Health related issues (public/workers» radiation doses, workers» physical safety, etc.)
- Social/political aspects (political acceptability, public reassurance and confidence, socio-psychological effects, equity, environmental protection, etc.)
- Technical feasibility (costs, available resources, waste management, etc.)

Effectiveness and overall benefit of the protective measures depend greatly on how the taken measures are communicated to the public. Risk communication is a key element in all crisis management. Communications should be as open as possible, timely, and presented in a way that the average citizen is able to understand it. Also the bases for the protective measures should be communicated in order to maintain public trust and confidence in authorities. Therefore the transparency in decision making is essential. In a case of malevolent and intentional dispersion of radioactive material into the environment there might be certain things which shall be kept confidential, because these situations are under criminal investigation.

The response to a nuclear or radiological emergency may involve many organizations. The functions of many of these organizations would be the same for a nuclear or radiological emergency as for a conventional emergency. However, the response to a nuclear or radiological emergency may also involve highly specialized agencies and technical experts. Therefore, in order to be effective, the response to a nuclear or radiological emergency must be well co-ordinated and arrangements must be appropriately integrated with those for a conventional emergency. In addition, the many misconceptions prevalent concerning nuclear and radiological emergencies and the possible health effects of radiation exposure could lead to inappropriate actions being taken. Consequently, preplanning on the basis of established principles of radiation protection and safety is essential. Such preplanning can be achieved only through a co-ordinated approach.

Safety Requirements publications establishes requirements for: common concepts and expectations; the clear allocation of responsibilities among all response organizations; well defined agreements between these organizations; and arrangements for co-ordinating an integrated response. The requirements derive their force from the provisions of the IAEA Statute and they also provide guidance for the operations of the Inter-Agency Committee for Response to Nuclear Accidents (IACRNA)[1].

Safety Requirements is established the requirements for an adequate level of preparedness and response for a nuclear or radiological emergency in any State. Their implementation is intended to minimize the consequences for people, property and the environment of any nuclear or radiological emergency.

The fulfilment of these requirements will also contribute to the harmonization of arrangements in the event of a transnational emergency. These requirements are intended to be applied by authorities at the national level by means of adopting legislation, establishing regulations and assigning responsibilities.

The requirements apply to all those practices and sources that have the potential for causing radiation exposure or environmental radioactive contamination warranting an emergency intervention and that are:

– Used in a State that chooses to adopt the requirements or that requests any of the sponsoring organizations to provide for the application of the requirements;

– Used by States with the assistance of the FAO, IAEA, ILO, PAHO, OCHA or WHO in compliance with applicable national rules and regulations;

– Used by the IAEA or which involve the use of materials, services, equipment, facilities and non-published information made available by the IAEA or at its request or under its control or supervision; or

– Used under any bilateral or multilateral arrangement whereby the parties request the IAEA to provide for the application of the requirements.

The terms «nuclear or radiological emergency», «planned exposure situation», «emergency exposure situation» and «existing exposure situation» are defined in GSR Part 7 and in IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. The definitions from GSR Part 7 are as follows:

> **emergency**. A non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human life, health, property or the environment.
>
> - This includes nuclear and radiological emergencies and conventional emergencies such as fires, releases of hazardous chemicals, storms or earthquakes.
> - This includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard.

[1] Preparedness and response for a nuclear or radiological emergency: GS-R-2. — Vienna: International Atomic Energy Agency, 2002.

nuclear or radiological emergency. An emergency in which there is, or is perceived to be, a hazard due to:

(a) The energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction;

(b) Radiation exposure.

emergency exposure situation. A situation of exposure that arises as a result of an accident, a malicious act or other unexpected event, and requires prompt action in order to avoid or reduce adverse consequences.

existing exposure situation. …a situation of exposure that already exists when a decision on the need for control needs to be taken.

- Existing exposure situations include exposure to natural background radiation that is amenable to control; exposure due to residual radioactive material that derives from past practices that were never subject to regulatory control; and exposure due to residual radioactive material deriving from a nuclear or radiological emergency after an emergency has been declared to be ended.

"**planned exposure situation.** …a situation of exposure that arises from the planned operation of a source or from

Requirement 4 of GSR Part 7 requires the government to ensure that a hazard assessment is performed to provide a basis for a graded approach in preparedness and response for a nuclear or radiological emergency. Five emergency preparedness categories are used to group the assessed hazards in relation to facilities, activities and sources (and their potential consequences) and to establish a basis for developing generically justified and optimized arrangements for emergency preparedness and response. Paragraph 5.14 of GSR Part 7 requires that, on the basis of the hazard assessment, a system be established for promptly classifying a nuclear or radiological emergency warranting protective actions and other response actions. Declaration of an emergency class initiates a coordinated and preplanned level of emergency response on the site and, where appropriate, off the site, in accordance with the protection strategy. GS-G-2.1 provides further guidance in this regard.

With account taken of the uncertainties in, and the limitations of, the information available at the preparedness stage, the hazard assessment identifies facilities and activities, on-site areas, off-site areas and locations for which a nuclear or radiological emergency might warrant the implementation of protective actions and other response actions. Facilities and activities, on-site areas, off-site areas and locations for which actions aimed at enabling the termination of the emergency may also be warranted should be identified as well.

The government, the response organizations and the operating organization should use the hazard assessment and the postulated nuclear or radiological emergencies within each emergency class to anticipate what the transition phase might encompass; the government, the response organizations and the operating organization should also aim to foresee the level of response warranted in relation to the transition phase for a range of postulated nuclear or radiological emergencies and thus provide a basis for applying a graded approach as follows:

- For a *general emergency* at a facility in emergency preparedness category I or II, leading to a significant release of radioactive material to the environment (e.g. the Fukushima Daiichi accident in 2011, GSG-11), termination of the emergency will take place through transition to an existing exposure situation.
- For a *site area emergency* at a facility in emergency preparedness category I or II and for a *facility emergency* at a facility in emergency preparedness category I, II or III, termination of the emergency will take place through transition to a planned exposure situation (e.g. the Paks fuel damage incident in 2003, GSG-11). In this context, the planned exposure situation may be associated with a continuation of normal operation, or with cleanup and decommissioning, or with the ending of the operational life of the source involved in the emergency, as applicable. However, postulated nuclear or radiological emergencies within these classes are not expected to result in a different exposure situation for the public compared with the situation that existed before the emergency.

- An *alert* at a facility in emergency preparedness category I, II or III will be followed by the resumption of normal operations in a planned exposure situation.
- *Other nuclear or radiological emergency* covers a broad spectrum of emergencies involving activities or acts in emergency preparedness category IV and may occur at any location (see para. 4.19 of GSR Part 7). In this class, depending on the type of emergency, termination of the emergency is envisaged by transition to either an existing exposure situation or a planned exposure situation. For example:
  - An emergency without a release of radioactive material to the environment is to be terminated by transition to the same exposure situation for the affected public that existed before the emergency (e.g. the radiological incident in Hueypoxtla, Mexico, in 2013, GSG-11). The recovered source may be brought back to normal operation or its operational life may be ended. In the latter case, the source may be managed as radioactive waste under the requirements for a planned exposure situation.
  - An emergency with a release of radioactive material to the environment resulting in significant residual radioactivity in the environment is to be terminated by transition to an existing exposure situation (e.g. the Goiânia accident of 1987, GSG-11).

The insights gained through the hazard assessment should be used for the identification of options and limitations of specific emergency arrangements to be made for the transition phase, including for the estimation of the time frames in which the prerequisites in Section 3 might be fulfilled, with account taken of:

- The likely inability to predict accurately when, where and what the actual impact of the nuclear or radiological emergency might be;
- The complexity of potential recovery efforts;
- The potential impact of non-radiological factors, such as public concerns and the political situation, on decision making at the time of the emergency.

For example, more detailed planning can be made for a general emergency at a facility in emergency preparedness category I (e.g. a nuclear power plant), particularly for the urgent response phase and the early response phase. In this case, aspects such as the potentially affected areas, the habits and customs of the potentially affected population and land use can be identified at the preparedness stage as part of the hazard assessment. A radiological emergency involving a dangerous source can occur at any location, and therefore a more generic approach towards preparedness would need to be adopted

An emergency may result in changes in the hazards applicable to the State compared with the hazards applicable before the emergency. Such a change may necessitate adjustment of the emergency arrangements (i.e. the revision of existing emergency arrangements and/or the introduction of new arrangements to manage the new hazards) in line with paras 4.26 and 4.27 of GSR Part 7.

As a result, before a decision to terminate the emergency can be made, a thorough hazard assessment of the situation and its future development should be performed in accordance with Requirement 4 of GSR Part 7. The implications of this hazard assessment on the existing emergency arrangements should also be identified and addressed.

Plans and procedures

Requirement 23 of GSR Part 7 requires that emergency plans, procedures and other arrangements be established at the preparedness stage for an effective response to a nuclear or radiological emergency. In order to ensure a timely and effective response from the onset of the emergency until the time the emergency is terminated, these arrangements should cover the transition phase in accordance with the guidance provided in GSG-11.

The emergency plans, procedures and other arrangements for the transition phase should be developed by all relevant organizations (with account taken of the results from the hazard assessment) in a manner that will allow for the effective implementation of the protection strategy, which includes considerations for meeting the prerequisites in Section 3 GSG-11.

As more organizations and parties become involved in the response during the transition phase, the national emergency plan developed in line with para. 6.17 of GSR Part 7 should clearly describe the roles and responsibilities of all relevant actors during the transition phase and beyond. The national emergency plan should take into account any changes in the authority and discharge of responsibilities between different phases, the triggering mechanism for this change, the coordination arrangements, the decision making processes and criteria, the necessary human resources, the type of data and information that needs to be transferred or made accessible by relevant parties and the arrangements and mechanism for carrying out such actions.

Future challenges in emergency management

Everyone should take a stand so that the radiological emergencies will arise also in the future. We just don`t know when and where, and what are the reasons for future emergencies. We have thousands of nuclear reactors and other facilities handling major radioactive and nuclear materials all around the world. Being aware that every man-made facility or equipment is always at risk for malfunction or an accident, it is more than likely that bigger or smaller nuclear incidents and accidents will happen from time to time. Risk for nuclear accidents is today very small, but when the risk comes true it will have multidimensional consequences in the society. In addition to nuclear facilities, there are in the world tens of thousands of smaller installations using radioactive sources and materials. Of course incidents and accidents in connection with them would have more limited radiological consequences compared with big nuclear facilities. However, sources could possibly be stolen or bought by persons with malicious intent, and applied in devices purposely designed to harm people and create anxiety and disruption.

Terrorism with nuclear and radioactive materials and illicit trafficking of radioactive and nuclear explosive devices and materials threaten the safety and security of all nations. Effective intelligence and radiation detection systems, intended to improve the capability to detect and interdict nuclear and radiological threats, are becoming increasingly important to all nations. International co-operation is necessity to success in this task and will strengthen national and international capabilities to combat nuclear terrorism.

International co-operation is a requirement also in the traditional emergency preparedness and response. Globalisation can be seen as a challenge, when people are travelling more and more, and all nations try to protect them also when being abroad. But globalisation can be seen also as an opportunity if nations exploit the modern information technology and co-operate with each other. The challenges we have in the near future in management of nuclear or radiological emergencies are related e.g. to the following issues:

- use of compatible methodologies, taking into account the experiences we have from the past emergency situations,
- how to develop the existing decision support tools and methods to take into account long-lasting releases of radioactivity into the environment, releases of radioactivity into water bodies, etc.,
- how to guarantee access to reliable information about the situation, when the accident site is far from our own country,
- how to deal with contaminated goods,
- what kind of radiation detection techniques we need in combating nuclear terrorism,
- information to and communication with the public.

These issues have been under living discussion in Europe when the European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery (NERIS Platform) was established in 2010-2011. The greatest challenge facing emergency and post accident management of a nuclear or radiological event in Europe is to organise an effective joint European cooperation in a complex social and political situation resulting from a major nuclear accident or malevolent act involving nuclear or other radioactive material. European countries have various cultural backgrounds and there are differences in administrative cultures and legislations. The NERIS Platform will promote transparent decision making and compatible technologies and methods to be used for prevention and consequence management of nuclear or radiological emergencies.

Transparency and broad participation of different stakeholders in decision making is the basic condition for effective cooperation at the European, regional and national levels and is now largely acknowledged by European organisations and national/international conventions. The Platform is open to all European organisations concerned with nuclear and radiological emergency response and recovery preparedness having expressed their interest in the activities of the Platform and having signed the Terms of Reference.The general goal in Europe should be that people are equally protected in case of a radiological emergency regardless of their residence.

IDENTIFYING, NOTIFYING A NUCLEAR OR RADIOLOGICAL EMERGENCY AND ACTIVATING AN EMERGENCY RESPONSE

Emergency classification system

Accidents happen. Aircraft crash, ships sink, trains derail, chemical factories explode, dams break, and nuclear power plants fail. We also face natural disasters such as floods, droughts, hurricanes and typhoons, earthquakes, heat waves, volcanic eruptions, tornados, meteor strikes, forest fires, ice storms, mud slides, and tsunami.

Each of these can shake a city, region, or nation. A few have shaken the world. The consequences can be political, societal, environmental, economic, and, most of all, human. At the heart of accidents and disasters are personal consequences. The most obvious of these are physical injury and death, sometimes on a massive scale. On 3 December 1984, a leak from a pesticide factory in Bhopal, India killed at least 3000 people and more than 100,000 suffered permanent disability. Compensation for injury was awarded to more than half a million people.

These figures are staggering, but looking more deeply reveals that the consequences of accidents and disasters go far beyond the obvious. A flood can destroy a village, washing away homes that have stood for generations and destroying culturally significant places, breaking a community»s connection with its own history. Releases from facilities can taint entire regions whether there are immediate health consequences or not.

Even if people can continue to live there, property values drop, populations dwindle, and job opportunities disappear as new people and businesses are reluctant to move in. Looking even more closely, consider the despair of grandparents whose grandchildren will no longer visit them in their homes, or families that break apart because of conflicting priorities. Learning to deal with accidents and natural disasters is essential to reduce human suffering and environmental impacts.

Everyone hopes that there will never be another nuclear accident on the scale of what occurred in 2011 at the Fukushima Daiichi nuclear power plant in Japan, or, even worse, in 1986 at the Chernobyl nuclear power plant in the USSR. Today, there are approximately 440 nuclear power reactors supplying electricity globally, and approximately 15 more are under construction (WNA, 2020).

ICRP has no position on nuclear power beyond the ethical principles and fundamental recommendations that apply universally. Ethically, this means that good must be preferred over harm, actions must be well informed and carefully considered, and people must be treated fairly and with dignity. We call these the four core ethical values of beneficence/non-maleficence, prudence, justice, and dignity (ICRP, 2018).

To enact these, we use the three principles of radiological protection: justification, optimisation of protection, and individual dose limitation. Respectively, these ensure that good outweighs harm, that protection is the best for the circumstances, and that an unfair dose is not imposed on any individual. In short, ICRP`s aim in all circumstances is to ensure that, where ionising radiation is involved, people and the environment are protected. Given this, ICRP applauds all efforts to improve nuclear safety (e.g. NEA, 2016).

Our mission is to promote radiological protection. Avoiding and mitigating nuclear accidents, especially those that release radioactive material, are part of protecting people and the environment from detrimental exposures to radiation. Nonetheless, we must be prepared for another accident. This is an important part of our work, related not only to nuclear power but also, for example, the use of radiation in medicine [see, for example, Publication 112 «Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies» (ICRP, 2009a)].

The present publication updates and replaces two previous publications, coincidentally released in the same year as Publication 112, and less than 2 years before the Fukushima Daiichi accident: Publication 109 «Application of the Commission»s Recommendations for the Protection of People in Emergency Exposure Situations» (ICRP, 2009b); and Publication 111 «Application of the Commission»s Recommendations to the Protection of People Living in Long-term Contaminated Areas» (ICRP, 2009c). In theory, the scope of the present publication is narrower than that of Publications 109 and 111, as it applies specifically to large nuclear accidents. In practice, these previous publications focused largely on these types of accidents, although the general principles are the same for accidents of almost any scale.

Even so, additional recommendations on radiological protection for other types of accidents are being considered. One of the advantages of combining the two previous publications into one is that the response can be considered more holistically, and more attention can be paid to the transition from the early and intermediate phases to the long-term phase of the accident. The current publication makes it easier to follow the thread through the emergency response to the recovery process, and importantly includes advice on preparation for the long-term phase.

10 years of experience following the Fukushima Daiichi accident, and 35 years after Chernobyl accident show the social impacts of the Chernobyl accident in light of the Fukushima Daiichi accident, and the Fukushima Daiichi accident has taught us that there can be enormous impacts even without immediate and widespread catastrophic health impacts. Reporting on the Fukushima Daiichi accident, the United Nations Scientific Committee on the Effects of Atomic Radiation noted that «no radiationrelated deaths or acute diseases have been observed among the workers and general public exposed to radiation from the accident» and «no discernible increased incidence of radiation-related health effects are expected among exposed members of the public or their descendants»; however «the most important health effect is on mental and social well-being» (UNSCEAR, 2013). Over nearly a decade, ICRP embarked on what was perhaps its most extensive work stream since the development of our last fundamental recommendations (ICRP, 2007).

Why do radiation accidents occur?

The main causes of radiation accidents in various application areas:

- lack of information on usual physical appearance and possible harm of radiation sources which may lead to accidental overexposure in case of unauthorised possession;
- insufficiency of radiation protection and radiation safety regulations, or their deficient application;
- violation of radiation protection and radiation safety procedures;
- human error due to insufficient knowledge of radiation protection and radiation safety regulations;
- insufficient or inappropriate training of radiation protection and radiation safety rules and regulations;
- inappropriate application of gamma sources and X-ray machines in industrial radiography and production control;
- unauthorised repair of gamma sources and X-ray machines in industrial radiography and production control;
- misuse, including misadministration of ionizing radiation or radioactive substances for diagnostic radiology, nuclear medicine and radiotherapy (X-ray generating machines and gamma ray sources, particle accelerators, and sealed or unsealed radionuclide sources);
- misuse of gamma sources in the sterilization and preservation of foodstuff or for other purposes;
- negligent and/or unregulated disposal of radiation sources and/or radioactive waste.

A large nuclear accident causes a breakdown in society affecting all aspects of individual and community life. It has large and long-lasting societal, environmental, and economic consequences.

Characterisation of the radiological situation on-site and off-site is essential to guide protective actions, and should be conducted as quickly as possible.

Standarts recommends using reference levels to guide the implementation of protective actions during the early, intermediate, and long-term phases of an accident.

The objective of radiological protection is to mitigate radiological consequences for people and the environment whilst, at the same time, ensuring sustainable living conditions for the affected people, suitable working conditions for the responders, and maintaining the quality of the environment.

Responders, who are likely to be the most exposed individuals, should be provided with appropriate protection, taking into account the requirements of the response onsite and off-site.

Responsible organisations should promote the involvement of local communities in a co-operative process with experts (co-expertise process) to help achieve a better assessment of the local situation, the development of an adequate practical radiological protection culture, and informed decision-making among those affected.

Preparedness planning is essential for mitigating the consequences during phases of a large nuclear accident, and should involve stakeholders.

Efforts to model the consequences of major reactor accidents predate operation of the first commer- cial power reactors and have been updated periodically since then.

The most current consequence study is State of the Art Reactor Consequence Analyses (NRC, 2007f). The code is specific to two selected reactor sites and includes consideration of the effects of specific emergency preparedness activities on population dose. The results were published as NUREG-1935 (NRC, 2012h), with supporting technical information in NUREG/CR-7110 (NRC, 2013f). The overall conclusions were that:

1) existing resources and procedures can stop an accident, slow it down, or reduce its impact before it can affect public health;
2) uncontrolled accidents take much longer to happen and release much less radioactive material than earlier analyses suggested; and
3) the analyzed accidents would cause essentially zero immediate deaths and only a very, very small increase in the risk of long-term cancer deaths. Also see NUREG/BR-0359 (NRC, 2012d).

Another study that may be of interest for emergency preparedness is NUREG-2161, which provides consequence estimates of a hypothetical spent fuel pool accident occurring at a specific reference plant. The study compares high-density and low-density loading conditions and assesses the benefits of post-9/11 mitigation measures.

The study concludes that spent fuel pools are robust structures that are likely to withstand severe earthquakes without leaking, with results that are comparable to past analyses.

International scheme

In 1989, the International Atomic Energy Agency and the Organization for Economic Cooperation and Development (Nuclear Energy Agency) jointly developed the International Nuclear Event Scale, as a means to report safety-related events to the International Atomic Energy Agency and its member countries. The scale uses a nine-tier classification scheme, from least significant to most significant, and is intended to apply to any incident involving radiation or radioactive material, including accidents occurring during the transport of radioactive materials or waste. The scale refers to all events not involving reactor or fuel damage as incidents and to those resulting in reactor core damage or fuel damage as accidents. The classification of a particular event depends on the number of failed safety systems (barriers, degradation of defense in depth), the onsite radiological impact and reactor or fuel damage, and the offsite radiological impact. An International Atomic Energy Agency pamphlet (IAEA, 1999c) states, in part:

- Although the Scale is designed for prompt use following an event, there will be occasions when a longer time-scale is required to understand and rate the consequences of an event. … The Scale does not replace the criteria already adopted nationally and internationally for the technical analysis and reporting of events to Safety Authorities. Neither does it

> form a part of the formal emergency arrangements that exist in each country to deal with radiological accidents. … It is not appropriate to use the Scale to compare safety performance among countries. Each country has different arrangements for reporting minor events to the public, and it is difficult to ensure precise international consistency in rating events at the boundary between level 0 and level 1. The statistically small number of such events, with vari- ability from year to year, makes it difficult to provide meaningful international comparisons.

According to the International Atomic Energy Agency,

- The 1986 accident at Chernobyl would have been classified at Level 7 (Major Accident).
- The 1957 accident at the Kyshtym reprocessing plant in Russia, which required offsite evacuation, would have been classified at Level 6 (Serious Accident).
- The 1957 accident at Windscale (since renamed Sellafield) in Cumbria, U.K., and the 1979 accident at Three Mile Island would have been classified at Level 5 (Accident with Offsite Risk).
- The 1973 accident at Sellafield, which released radioactive material onsite, and the 1980 accident at the Saint Laurent reactor in France, which resulted in a damaged reactor core but no offsite release, would have been classified at Level 4 (Accident without Offsite Risk).
- The 1999 inadvertent criticality event at Tokaimura in Japan was classified at Level 4.
- The 1989 fire at the Vandellos plant in Spain, which severely damaged reactor safety systems but did not result in core damage, would have been classified at Level 3.

The United States did not participate in drafting the event scale and at first did not support its use. A change to this position occurred in 1992 via a Generic Letter (NRC, 1992f) that communicated the decision to report reactor events to the IAEA using the International Scale if they were associated with an emergency classification of Alert or higher. The United States committed to evaluate the event, complete the associated rating form, and submit the rating form, rather than having licensees make the IAEA report.

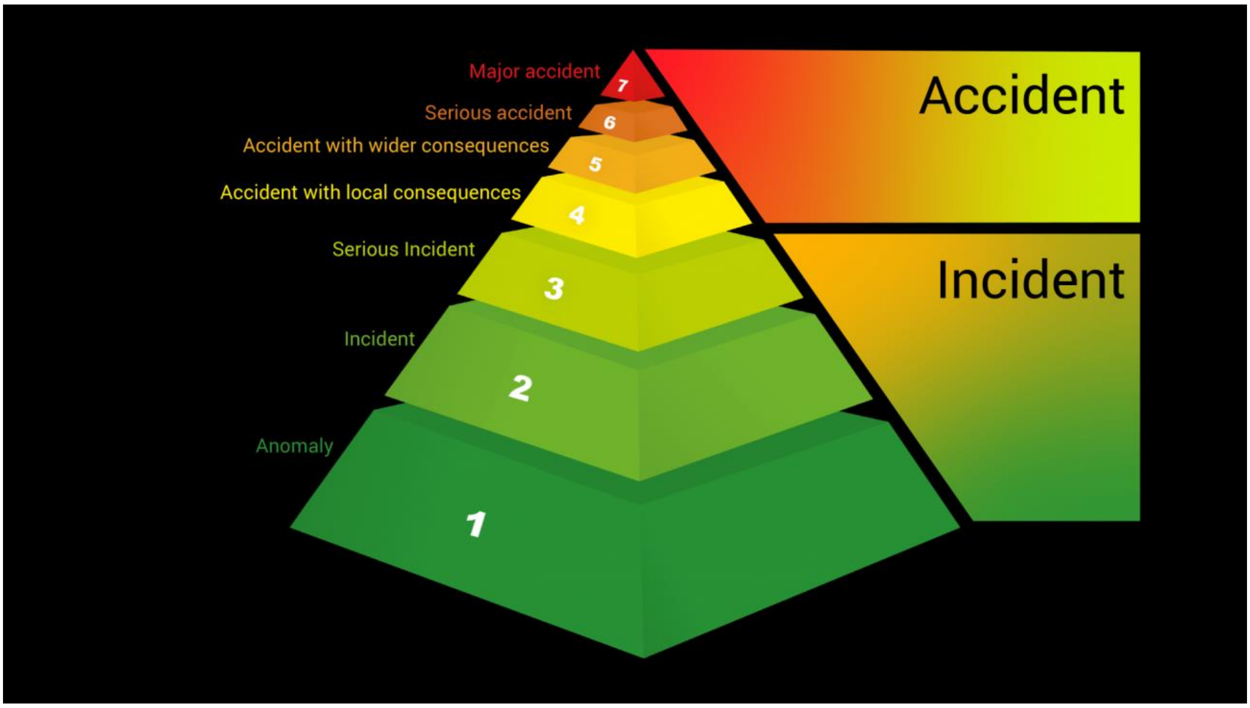

Fig 2. INES Scale

The INES Scale is a worldwide tool for communicating to the public in a consistent way the safety significance of nuclear and radiological events. Just like information on earthquakes or temperature would be difficult to understand without the Richter or Celsius scales, the INES Scale explains the significance of events from a range of activities, including industrial and medical use of radiation sources, operations at nuclear facilities and transport of radioactive material.

Major Accident Level 7
Serious Accident Level 6
Accident with Wider Consequences Level 5
Accident with Local Consequences Level 4
Serious Incident Level 3
Incident Level 2
Anomaly Level 1
NO SAFETY SIgNIFICANCE *(Below Scale/ Level 0)*

Events are classified on the scale at seven levels: Levels 1–3 are called "incidents" and Levels 4–7 "accidents". The scale is designed so that the severity of an event is about three times greater for each increase in level on the scale. Events without safety significance are called “deviations” and are classified Below Scale / Level 0.

INES classifies nuclear and radiological accidents and incidents by considering three areas of impact:

People and the Environment considers the radiation doses to people close to the location of the event and the widespread, unplanned release of radioactive material from an installation.

Radiological Barriers and Control covers events without any direct impact on people or the environment and only applies inside major facilities. It covers unplanned high radiation levels and spread of significant quantities of radioactive materials confined within the installation.

Defence-in-Depth also covers events without any direct impact on people or the environment, but for which the range of measures put in place to prevent accidents did not function asintended.

Communicating Events

Nuclear and radiological events are promptly communicated by the INES Member States, otherwise a confused understanding of the event may occur from media or from public speculation. In some situations, where not all the details of the event are known early on, a provisional rating may be issued. Later, a final rating is determined and any differences explained.

Table 2

Examples of events at nuclear facilities

	People and Environment	Radiological Barriers and Control	Defence-in-Depth
7	Chernobyl, 1986 – Widespread health and environmental effects. External release of a significant fraction of reactor core inventory.		
6	Kyshtym, Russia, 1957 – Significant release of radioactive material to the environment from explosion of a high activity waste tank.		
5	Windscale Pile, UK, 1957 – Release of radioactive material to the environment following a fire in a reactor core.	Three Mile Island, USA, 1979 – Severe damage to the reactor core.	
4	Tokaimura, Japan, 1999 – Fatal overexposures of workers following a criticality event at a nuclear facility.	Saint Laurent des Eaux, France, 1980 – Melting of one channel of fuel in the reactor with no release outside the site.	
3	No example available	Sellafield, UK, 2005 — Release of large quantity of radioactive material, contained within the installation.	Vandellos, Spain, 1989 — Near accident caused by fire resulting in loss of safety systems at the nuclear power station.
2	Atucha, Argentina, 2005 – Overexposure of a worker at a power reactor exceeding the annual limit.	Cadarache, France, 1993 — Spread of contamination to an area not expected by design.	Forsmark, Sweden, 2006 — Degraded safety functions for common cause failure in the emergency power supply system at nuclear power plant.
1			Breach of operating limits at a nuclear facility.

To facilitate international communications for events attracting wider interest, the IAEA maintains a web-based communications network that allows details of the event to immediately be made publicly available.

The two tables that follow show selected examples of historic events rated using the INES scale, ranging from a Level 1 anomaly to a Level 7 major accident; a much wider range of examples showing the rating methodology is provided in the INES Manual.

Table 3

General description of INES levels

INES Level	People and Environment	Radiological Barriers and Control	Defence-in-Depth
Major Accident Level 7	Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		
Serious Accident **Level 6**	Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with Wider Consequences Level 5	• Limited release of radioactive material likely to require implementation of some planned countermeasures. • Several deaths from radiation.	• Severe damage to reactor core. • Release of large quantities of radioactive material within an installation with a high probability of significant public exposure. This could arise from a major criticality accident or fire.	
Accident with Local Consequences Level 4	• Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. • At least one death from radiation.	• Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. • Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious Incident Level 3	• Exposure in excess of ten times the statutory annual limit for workers. • Non-lethal deterministic health effect (e.g., burns) from radiation.	• Exposure rates of more than 1 Sv/h in an operating area. • Severe contamination in an area not expected by design, with a low probability of significant public exposure.	• Near accident at a nuclear power plant with no safety provisions remaining. • Lost or stolen highly radioactive sealed source. • Misdelivered highly radioactive sealed source without adequate procedures in place to handle it.
Incident Level 2	• Exposure of a member of the public in excess of 10 mSv. • Exposure of a worker in excess of the statutory annual limits.	• Radiation levels in an operating area of more than 50 mSv/h. • Significant contamination within the facility into an area not expected by design.	• Significant failures in safety provisions but with no actual consequences. • Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. • Inadequate packaging of a highly radioactive sealed source.
Anomaly Level 1			• Overexposure of a member of the public in excess of statutory annual limits. • Minor problems with safety components with significant defence-in-depth remaining. • Low activity lost or stolen radioactive source, device or transport package.

Scope of the Scale

INES applies to any event associated with the transport, storage and use of radioactive material and radiation sources, whether or not the event occurs at a facility. It covers a wide spectrum of practices, including industrial use such as radiography, use of radiation sources in hospitals, activity at nuclear facilities, and transport of radioactive material.

It also includes the loss or theft of radioactive sources or packages and the discovery of orphan sources, such as sources inadvertentlytransferred into the scrap metal trade.

When a device is used for medical purposes (e.g., radiodiagnosis or radiotherapy), INES isused for the rating of events resulting in actualexposure of workers and the public, or involving degradation of the device or deficienciesin the safety provisions. Currently, the scale does not cover the actual or potential con- sequences for patients exposed as part of a medical procedure.

The scale is only intended for use in civil (non-military) applications and only relates to the safety aspects of an event. INES is not intended for use in rating security-related events or malicious acts to deliberately exposepeople to radiation.

What the Scale is Not For

It is not appropriate to use INES to compare safety performance between facilities, organizations or countries. The statistically small numbers of events at Level 2 and above and the differences between countries for reporting moreminor events to the public make it inappropriateto draw international comparisons.

History

Since 1990 the scale has been applied to classify events at nuclear power plants, then extended to enable it to be applied to all installations associated with the civil nuclear industry. By 2006, it had been adapted to meet the growing need for communication of the significance of all events associated with the transport, storage and use of radioactive material and radiation sources.

The IAEA has coordinated its development in cooperation with the OECD/NEA and with the support of more than 60 Member States through their officially designated INES National Officers.

Table 4

Examples of events involving radiation sources and transport

	People and Environment	Defence-in-Depth
7		
6		
5	*Goiânia, Brazil, 1987* — Four people died and six received doses of a few gy from an abandoned andruptured highly radioactive Cs-137 source.	
4	*Fleurus, Belgium, 2006* — Severe health effects for aworker at a commercial irradiation facility as a result of high doses of radiation.	
3	*Yanango, Peru, 1999* — Incident with radiography source resulting in severe radiation burns.	*Ikitelli, Turkey, 1999* — Loss of a highly radioactiveCo-60 source.
2	*USA, 2005* — Overexposure of a radiographer exceedingthe annual limit for radiation workers.	*France, 1995* — Failure of access control systemsat accelerator facility.
1		Theft of a moisture-density gauge.

The current version of the INES manual was adopted 1 July 2008. With this new edition, it is anticipated that INES will be widely used bythe Member States and become the world- wide scale for putting into the proper perspective the safety significance of nuclear and radiation events.

General description of the scale

Events are classified on the scale at seven levels: Levels 4–7 are termed «accidents» and Levels 1–3 «incidents». Events without safety significance are classified as «Below Scale/Level 0». Events that have no safety relevance with respect to radiation or nuclear safety are not classified on the scale.

For communication of events to the public, a distinct phrase has been attributed to each level of INES. In order of increasing severity, these are: «anomaly», «incident», «serious incident», «accident with local consequences», «accident with wider consequences», «serious accident» and «major accident».

The aim in designing the scale was that the severity of an event would increase by about an order of magnitude for each increase in level on the scale (i.e. the scale is logarithmic). The 1986 accident at the Chernobyl nuclear power plant is rated at Level 7 on INES. It had widespread impact on people and the environment. One of the key considerations in developing INES rating criteria was to ensure that the significance level of less severe and more localized events were clearly separated from this very severe accident. Thus the 1979 accident at the Three Mile Island nuclear power plant is rated at Level 5 on INES, and an event resulting in a single death from radiation is rated at Level 4. The structure of the scale is shown in Table 3. Events are considered in terms of their impact on three different areas: impact on people and the environment; impact on radiological barriers and controls at facilities; and impact on defence in depth. Detailed definitions of the levels are provided in the later sections of this manual.

The impact on people and the environment can be localized (i.e. radiation doses to one or a few people close to the location of the event, or widespread as in the release of radioactive material from an installation). The impact on radiological barriers and controls at facilities is only relevant to facilities handling major quantities of radioactive material such as power reactors, reprocessing facilities, large research reactors or large source production facilities. It covers events such as reactor core melt and the spillage of significant quantities of radioactive material resulting from failures of radiological barriers, thereby threatening the safety of people and the environment

Those events rated using these two areas (people and environment, and radiological barriers and controls) are described in this manual as events with “actual consequences.” Reduction in defence in depth principally covers those events with no actual consequences, but where the measures put in place to prevent or cope with accidents did not operate as intended.

Level 1 covers only degradation of defence in depth. Levels 2 and 3 cover more serious degradations of defence in depth or lower levels of actual consequence to people or facilities. Levels 4 to 7 cover increasing levels of actual consequence to people, the environment or facilities.

Although INES covers a wide range of practices, it is not credible for events associated with some practices to reach the upper levels of the scale. For example, events associated with the transport of sources used in industrial radiography could never exceed Level 4, even if the source was taken and handled incorrectly.

The scale can be applied to any event associated with the transport, storage and use of radioactive material and radiation sources. It applies whether or not the event occurs at a facility. It includes the loss or theft of radioactive sources or packages and the discovery of orphan sources, such as sources inadvertently transferred into the scrap metal trade. The scale can also be used for events involving the unplanned exposure of individuals in other regulated practices (e.g. processing of minerals).

The scale is only intended for use in civil (non-military) applications and only relates to the safety aspects of an event. The scale is not intended for use in rating security-related events or malicious acts to deliberately expose people to radiation.

Description and INES Level	People and the environment	Radiological barriers and controls at facilities	Defence in depth
Major accident Level 7	- Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.		
Serious accident Level 6	- Significant release of radioactive material likely to require implementation of planned countermeasures.		
Accident with wider consequences Level 5	- Limited release of radioactive material likely to require implementation of some planned countermeasures. - Several deaths from radiation.	- Severe damage to reactor core. - Release of large quantities of radioactive material within an installation with a high probability of significant public exposure. This could arise from a major criticality accident or fire.	
Accident with local consequences Level 4	- Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. - At least one death from radiation.	- Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. - Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious incident Level 3	- Exposure in excess of ten times the statutory annual limit for workers. - Non-lethal deterministic health effect (e.g. burns) from radiation.	- Exposure rates of more than 1 Sv/hr in an operating area. - Severe contamination in an area not expected by design, with a low probability of significant public exposure.	- Near accident at a nuclear power plant with no safety provisions remaining. - Lost or stolen highly radioactive sealed source. - Misdelivered highly radioactive sealed source without adequate radiation procedures in place to handle it.
Incident Level 2	- Exposure of a member of the public in excess of 10mSv. - Exposure of a worker in excess of the statutory annual limits.	- Radiation levels in an operating area of more than 50 mSv/h. - Significant contamination within the facility into an area not expected by design.	- Significant failures in safety provisions but with no actual consequences. - Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. - Inadequate packaging of a highly radioactive sealed source.
Anomaly **Level 1**			- Overexposure of a member of the public in excess of statutory limits. - Minor problems with safety components with significant defence in depth remaining. - Low activity lost or stolen radioactive source, device or transport package.
	No safety significance (Below scale/Level 0)		

Fig. 3. General criteria for rating events in INES

When a device is used for medical purposes (e.g. radiodiagnosis and radiotherapy), the guidance in this manual can be used for the rating of events resulting in actual exposure of workers and the public, or involving degradation of the device or deficiencies in the safety provisions. Currently, the scale does not cover the actual or potential consequences on patients exposed as part of a medical procedure. The need for guidance on such exposures during medical procedures is recognized and will be addressed at a later date.

The scale does not apply to every event at a nuclear or radiation facility. The scale is not relevant for events solely associated with industrial safety or other events which have no safety relevance with respect to radiation or nuclear safety. For example, events resulting in only a chemical hazard, such as a gaseous release of non-radioactive material, or an event such as a fall or an electrical shock resulting in the injury or death of a worker at a nuclear facility would not be classified using this scale. Similarly, events affecting the availability of a turbine or generator, if they did not affect the reactor at power, would not be classified on the scale nor would fires if they did not involve any possible radiological hazard and did not affect any equipment associated with radiological or nuclear safety.

Principles of INES criteria

Each event needs to be considered against each of the relevant areas, namely: people and the environment; radiological barriers and controls; and defence in depth. The event rating is then the highest level from consideration of each of the three areas. The following sections briefly describe the principles associated with assessing the impact on each area.

People and the environment

The simplest approach to rating actual consequences to people would be to base the rating on the doses received. However, for accidents, this may not be an appropriate measure to address the full range of consequences. For example, the efficient application of emergency arrangements for evacuation of members of the public may result in relatively small doses, despite a significant accident at an installation. To rate such an event purely on the doses received does not communicate the true significance of what happened at the installation, nor does it take account of the potential widespread contami- nation. Thus, for the accident levels of INES (4–7), criteria have been developed based on the quantity of radioactive material released, rather than the dose received. Clearly these criteria only apply to practices where there is the potential to disperse a significant quantity of radioactive material.

In order to allow for the wide range of radioactive material that could potentially be released, the scale uses the concept of «radiological equivalence». Thus, the quantity is defined in terms of terabecquerels of ^{131}I, and conversion factors are defined to identify the equivalent level for other isotopes that would result in the same level of effective dose.

For events with a lower level of impact on people and the environment, the rating is based on the doses received and the number of people exposed.

(The criteria for releases were previously referred to as «off-site» criteria)

Radiological barriers and controls

In major facilities with the potential (however unlikely) for a large release of activity, where a site boundary is clearly defined as part of their licensing, it is possible to have an event where there are significant failures in radiological barriers but no significant consequences for people and the environment (e.g. reactor core melt with radioactive material kept within the containment). It is also possible to have an event at such facilities where there is significant contamination spread or increased radiation, but where there is still considerable defence in depth remaining that would prevent significant conse- quences to people and the environment. In both cases, there are no significant consequences to individuals outside the site boundary, but in the first case, there is an increased likelihood of such consequences to individuals, and in the second case, such failures represent a major failure in the management of radiological controls. It is important that the rating of such events on INES takes appropriate account of these issues.

The criteria addressing these issues only apply at authorized facilities handling major quantities of radioactive materials. (These criteria, together with the criteria for worker doses, were previously referred to as “on-site” criteria). For events involving radiation sources and the transport of radioactive material, only the criteria for people and the environment, and for defence in depth need to be considered.

Defence in depth

INES is intended to be applicable to all radiological events and all nuclear or radiation safety events, the vast majority of which relate to failures in equipment or procedures. While many such events do not result in any actual consequences, it is recognized that some are of greater safety significance than others. If these types of events were only rated based on actual consequences, all such events would be rated at “Below scale/Level 0”, and the scale would be of no real value in putting them into perspective. Thus, it was agreed at its original inception, that INES needed to cover not only actual consequences but also the potential consequences of events.

A set of criteria was developed to cover what has become known as “degradation of defence in depth.” These criteria recognize that all applications involving the transport, storage and use of radioactive material and radiation sources incorporate a number of safety provisions. The number and reliability of these provisions depends on their design and the magnitude of the hazard. Events may occur where some of these safety provisions fail but others prevent any actual consequences. In order to communicate the significance of such events, criteria are defined which depend on the amount of radioactive material and the severity of the failure of the safety provisions.

Since these events only involve an increased likelihood of an accident, with no actual consequences, the maximum rating for such events is set at Level 3 (i.e. a serious incident). Furthermore, this maximum level is only applied to practices where there is the potential, if all safety provisions failed, for a significant accident (i.e. one rated at Levels 5, 6 or 7 in INES). For events associated with practices that have a much smaller hazard potential (e.g. transport of small medical or industrial radioactive sources), the maximum rating under defence in depth is correspondingly lower.

One final issue that is addressed under defence in depth is what is described in this document as additional factors, covering as appropriate, common cause failure, issues with procedures and safety culture. To address these additional factors, the criteria allow the rating to be increased by one level from the rating derived solely by considering the significance of the actual equipment or administrative failures. (It should be noted that for events related to radiation sources and transport of radioactive material, the possibility of increasing the level due to additional factors is included as part of the rating tables rather than as a separate consideration.)

The detailed criteria developed to implement these principles are defined in this document. Three specific but consistent approaches are used; one for transport and radiation source events, one specific to events at power reactors in operation and one for events at other authorized facilities (including events at reactors during cold shutdown, research reactors and decommissioning of nuclear facilities). It is for this reason that there are three separate sections for defence in depth, one for each of these approaches. Each section is self- contained, allowing users to focus on the guidance relevant to events of interest.

The criteria for transport and radiation source events are contained in a set of tables that combine all three elements of defence in depth mentioned earlier (i.e. the amount of radioactive material, the extent of any failure of safety provisions and additional factors).

The criteria for power reactors in operation give a basic rating from two tables and allow additional factors to increase the rating by one level. The basic rating from the tables depends on whether the safety provisions were actually challenged, the extent of any degradation of the safety provisions and the likelihood of an event that would challenge such provisions.

The criteria for events at reactors in cold shutdown, research reactors and other authorized facilities give a basic rating from a table, depending on the maximum consequences, were all the safety provisions to fail, and the extent of the remaining safety provisions. This latter factor is accounted for by grouping safety provisions into what are called independent safety layers and counting the number of such safety layers. Additional factors are then considered by allowing a potential increase in the basic rating by one level.

The final rating

The final rating of an event needs to take account of all the relevant criteria described above. Each event should be considered against each of the appropriate criteria and the highest derived rating is the one to be applied to the event. A final check for consistency with the general description of the levels of INES ensures the appropriateness of the rating.

Emergency action levels (EALs) for different facilities and activities

For the purposes of the requirements nuclear and radiation related threats are grouped according to the threat categories shown in Table 4. The five threat categories in Table I establish the basis for developing generically optimized arrangements for preparedness and response. Threat categories I, II and III represent decreasing levels of threat at facilities and in the corresponding stringency of requirements for preparedness and response arrangements. Threat category IV applies to activities that can lead to emergencies occurring virtually anywhere; it is also the minimum level of threat, which is assumed to apply for all States and jurisdictions. Threat category IV always applies to all jurisdictions, possibly together with threats in other categories. Threat category V applies to the off-site areas where arrangements for preparedness and response are warranted to deal with contamination resulting from a release of radioactive material from a facility in threat category I or II.

Threat categories are used in this Safety Requirements publication to implement a graded approach to establishing and maintaining adequate arrangements for preparedness and response by establishing requirements that are commensurate with the potential magnitude and nature of the hazard as identified in a threat assessment.

The regulatory body shall require that arrangements for preparedness and response be in place for the on-site area for any practice or source that could necessitate an emergency intervention. For a facility in threat category I, II or III “Appropriate emergency [preparedness and response] arrangements shall be established from the time that nuclear fuel [or significant amounts of radioactive or fissile material] is brought to the site, and complete emergency preparedness as described here shall be ensured before the commencement of operation.”

The regulatory body shall ensure that such emergency arrangements are integrated with those of other response organizations as appropriate before the commencement of operation. The regulatory body shall ensure that such emergency arrangements provide a reasonable assurance of an effective response, in compliance with these requirements, in the case of a nuclear or radiological emergency.

The regulatory body shall require that the emergency arrangements “shall be tested in an exercise before the commencement of operation [of a new practice]. There shall thereafter at suitable intervals be exercises of the emergency [arrangements], some of which shall be witnessed by the regulatory body.”

“In planning for, and in the event of [a nuclear or radiological emergency], the regulatory body shall act as an adviser to the government and [response organizations] in respect of nuclear safety and radiation protection.”

Table 4

Five categories of nuclear and radiation related threats for the purposes of the requirements

Threat category	Description
I	Facilities, such as nuclear power plants, for which on-site eventsa (including very low probability events) are postulated that could give rise to severe deterministic health effectsb off the site, or for which such events have occurred in similar facilities.
II	Facilities, such as some types of research reactors, for which on-site eventsa are postulated that could give rise to doses to people off the site that warrant urgent protective action in accordance with international standardsc, or for which such events have occurred in similar facilities. Threat category II (as opposed to threat category I) does not include facilities for which on-site events (including very low probability events) are postulated that could give rise to severe deterministic health effects off the site, or for which such events have occurred in similar facilities.
III	Facilities, such as industrial irradiation facilities, for which on-site events are postulated that could give rise to doses that warrant or contamination that warrants urgent protective action on the site, or for which such events have occurred in similar facilities. Threat category III (as opposed to threat category II) does not include facilities for which events are postulated that could warrant urgent protective action off the site, or for which such events have occurred in similar facilties.
IV	Activities that could give rise to a nuclear or radiological emergency that could warrant urgent protective action in an unforeseeable location. These include non-authorized activities such as activities relating to dangerous sources obtained illicitly. They also include transport and authorized activities involving dangerous mobile sources such as industrial radiography sources, nuclear powered satellites or radiothermal generators. Threat category IV represents the minimum level of threat, which is assumed to apply for all States and jurisdictions.
V	Activities not normally involving sources of ionizing radiation, but which yield products with a significant likelihoodd of becoming contaminated as a result of events at facilities in threat category I or II, including such facilities in other States, to levels necessitating prompt restrictions on products in accordance with international standards

The system of protective actions and other response actions in an emergency (see Table 5) includes numerical values of generic criteria as well as of the corresponding operational criteria that form the basis for decision making in an emergency.

Table 5

System of protective actions and other response actions in an emergency

Types of possible health consequences of exposure	Basis for implementation of protective actions and other response actions	
	Projected dose	Dose received
Severe deterministic effects[a]	Implementation of precautionary urgent protective actions, even under adverse conditions, to prevent severe deterministic effects	Other response actions[b] for treatment and management of severe deterministic effects
Increase in stochastic effects	Implementation of urgent protective actions and initiation of early protective actions[c] to reduce the risk of stochastic effects as far as reasonably possible	Other response actions[d] for early detection and effective management of stochastic effects

[a] Generic criteria are established at levels of dose that are approaching the thresholds for severe deterministic effects.
[b] Such actions include immediate medical examination, consultation and treatment as indicated, contamination control, decorporation where applicable, registration for long term health monitoring, and comprehensive psychological counselling.
[c] Such actions include relocation and long term restriction of consumption of contaminated food.
[d] Such actions include screening based on individual doses to specific organs, considering the need for registration for medical follow-up and counselling to allow informed decisions to be made in individual circumstances.

Notifying of a nuclear or radiological emergency

Communicating emergency to the IAEA

When circumstances necessitate an emergency response, operators shall promptly determine the appropriate emergency class or the level of emergency response and shall initiate the appropriate on-site actions. The operator shall notify and provide updated information, as appropriate, to the off-site notification point.

Upon notification of a nuclear or radiological emergency warranting an off-site response, the off-site notification point shall promptly notify all appropriate off-site response organizations. Upon notification, the off-site response organizations shall promptly initiate the preplanned and co-ordinated response appropriate to the emergency class or the level of emergency.

Appropriate emergency response actions shall be initiated promptly upon the receipt of a notification from another State or information from the IAEA of a notification relating to an actual or potential transnational emergency that could affect the State or its nationals.

In the event of a transnational emergency the notifying State shall promptly notify directly or through the IAEA those States that may be affected. The notifying State shall also notify the IAEA of a transnational emergency upon recognition or when it notifies another State. The notifying State shall provide information concerning the nature of the emergency and any potential transnational consequences and shall respond to requests from other States and from the IAEA for information with the intent of minimizing the consequences.

Notification points shall be established that are responsible for receiving emergency notifications of an actual or potential nuclear or radiological emergency. The notification points shall be continuously available to receive any notification or request for assistance and to respond promptly or to initiate an off-site response.

In jurisdictions in which there is a significant probability of a dangerous source being lost, abandoned, illicitly removed or illicitly transported, arrangements shall be made to ensure that the on-site managers of operations and the local officials responsible for response are aware of the indicators of a potential emergency and aware of the appropriate notifications and other immediate actions warranted if an emergency is suspected.

Arrangements shall be made to ensure that first responders are aware of: the indicators of the presence of radiation or radioactive material, such as the trefoil symbol and 'dangerous goods' labels and placards, and the significance of these indicators; the symptoms that would indicate a need to conduct an assessment to determine whether there may be an emergency; and the appropriate notification and other immediate actions warranted if an emergency is suspected.

The operator of a facility or practice in threat category I, II, III or IV shall make arrangements for the prompt identification of an actual or potential nuclear or radiological emergency and determination of the appropriate level of response. This shall include a system for classifying all potential nuclear and radiological emergencies that warrant an emergency intervention to protect workers and the public, in accordance with international standards, which covers emergencies of the following types at facilities (1–4) and other emergencies such as (5) below:

1) General emergencies at facilities in threat category I or II involving an actual, or substantial risk of, release of radioactive material or radiation exposure that warrants taking urgent protective actions off the site. Upon declaration of this class of emergency, actions shall be promptly taken to mitigate the consequences and to protect people on the site and within the precautionary action zone and urgent protective action planning zone, as appropriate.

2) Site area emergencies at facilities in threat category I or II involving a major decrease in the level of protection for those on the site and near the facility. Upon declaration of this class of emergency, actions shall be promptly taken to mitigate the consequences, to protect people on the site and to make preparations to take protective actions off the site if this becomes necessary.

3) Facility emergencies at facilities in threat category I, II or III involving a major decrease in the level of protection for people on the site. Upon declaration of this class of emergency, actions shall be promptly taken to mitigate the consequences and to protect people on the site. Emergencies in this class can never give rise to an off-site threat.

4) Alerts at facilities in threat category I, II or III involving an uncertain or significant decrease in the level of protection for the public or people on the site. Upon declaration of this class of emergency, actions shall be promptly taken to assess and mitigate the consequences and to increase the readiness of the on-site and off-site response organizations, as appropriate.

5) Other emergencies such as an uncontrolled source emergency involving the loss, theft or lack of control of a dangerous source, including the re-entry of a satellite containing such a source.

An off-site notification point, or more than one, shall be established to receive notification of an actual or potential nuclear or radiological emergency. The notification point(s) shall be maintained in a state of continuous availability to receive any notification or request for support and to respond promptly, or to initiate a preplanned and coordinated off-site emergency response appropriate to the emergency class or the level of emergency response. The notification point(s) shall be able to initiate immediate communication by suitable, reliable and diverse means with the response organizations that are providing support.

For facilities in categories I and II and for areas in category V, the notification po int shall be able to initiate immediate communication with the authority that has been assigned the responsibility to decide on and to initiate precautionary urgent protective actions and urgent protective actions off the site.

For facilities and locations at which there is a significant likelihood of encountering a dangerous source that is not under control, arrangements shall be made to ensure that the on-site managers of operations and other personnel are aware of the indicators of a potential radiological emergency, the appropriate notification, and protective actions and other response actions that are immediately warranted in an emergency. For facilities and locations for which there is a significant likelihood of encountering a dangerous source that is not under control and for an emergency at an unforeseen location, arrangements shall be made to ensure that the local officials responsible for the response and first responders are aware of the indicators of a potential radiological emergency, the appropriate notification, and protective actions and other response actions that are warranted to be taken immediately in an emergency.

The operating organization of a facility or activity in category I, II, III or IV shall make arrangements for promptly classifying, on the basis of the hazard assessment, a nuclear or radiological emergency warranting protective actions and other response actions to protect workers, emergency workers, members of the public and, as relevant, patients and helpers in an emergency, in accordance with the protection strategy. This shall include a system for classifying all types of nuclear or radiological emergency as follows:

a) General emergency at facilities in category I or II for an emergency that warrants taking precautionary urgent protective actions, urgent protective actions, and early protective actions and other response actions on the site and off the site. Upon declaration of this emergency class, appropriate actions shall promptly be taken, on the basis of the available information relating to the emergency, to mitigate the consequences of the emergency on the site and to protect people on the site and off the site.

b) Site area emergency at facilities in category I or II for an emergency that warrants taking protective actions and other response actions on the site and in the vicinity of the site. Upon declaration of this emergency class, actions shall promptly be taken: (i) to mitigate the consequences of the emergency on the site and to protect people on the site; (ii) to increase the readiness to take protective actions and other response actions off the site if this becomes necessary on the basis of observable conditions, reliable assessments and/or results of monitoring; and (iii) to conduct off-site monitoring, sampling and analysis.

c) Facility emergency at facilities in category I, II or III for an emergency that warrants taking protective actions and other response actions at the facility and on the site but does not warrant taking protective actions off the site.

Upon declaration of this emergency class, actions shall promptly be taken to mitigate the consequences of the emergency and to protect people at the facility and on the site. Emergencies in this class do not present an off-site hazard.

d) Alert at facilities in category I, II or III for an event that warrants taking actions to assess and to mitigate the potential consequences at the facility. Upon declaration of this emergency class, actions shall promptly be taken to assess and to mitigate the potential consequences of the event and to increase the readiness of the on-site response organizations.

e) Other nuclear or radiological emergency for an emergency in category IV that warrants taking protective actions and other response actions at any location. Upon declaration of this emergency class and the level of emergency response, actions shall promptly be taken to mitigate the consequences of the emergency on the site, to protect those in the vicinity (e.g. workers and emergency workers and the public) and to determine where and for whom protective actions and other response actions are warranted.

For facilities in category I, II or III and for category IV, arrangements shall be made to review the declared emergency class in the light of any new information and, as appropriate, to revise it.

The emergency classification system for facilities and activities in categories I, II, III and IV shall take into account all postulated emergencies, including those arising from events of very low probability. The operational criteria for classification shall include emergency action levels and other observable conditions (i.e. ‘observables’) and indicators of the conditions at the facility and/or on the site or off the site. The emergency classification system shall be established with the aim of allowing for the prompt initiation of an effective response in recognition of the uncertainty of the available information.

It shall be ensured that any process for rating an event on the International Nuclear and Radiological Event Scale (INES) does not delay the emergency classification or emergency response actions.

For facilities and activities in categories I, II and III, and for category IV, arrangements shall be made:

1) to promptly recognize and classify a nuclear or radiological emergency;

2) upon classification, to promptly declare the emergency class and to initiate a coordinated and preplanned on-site response;

3) to notify the appropriate notification point and to provide sufficient information for an effective off-site response; and

4) upon notification, to initiate a coordinated and preplanned off-site response, as appropriate, in accordance with the protection strategy. These arrangements shall include suitable, reliable and diverse means of warning persons on the site, of notifying the notification point and of communication between response organizations.

In the event of a transnational emergency, the notifying State shall promptly notify20,21 the IAEA of the emergency and, either directly or through the IAEA, those States that could be affected by it. The notifying State shall provide information on the nature of the emergency and on its potential transnational consequences, and shall respond to requests from other States and from the IAEA for information for the purposes of mitigating any consequences.

The State shall make known to the IAEA and to other States, directly or through the IAEA, its single warning point responsible for receiving emergency notifications and information from other States and information from the IAEA.

This warning point shall be maintained in a state of continuous availability to receive any notification, request for assistance or request for verification and to promptly initiate a response or verification. The State shall promptly inform the IAEA and shall inform other States, directly or through the IAEA, of any changes that occur in respect of the warning point. The State shall make arrangements for promptly notifying and for providing relevant information, directly or through the IAEA, to those States that could be affected by a transnational emergency.

The notifying State shall have arrangements in place for promptly responding to requests from other States or from the IAEA for information in respect of a transnational emergency, in particular with regard to minimizing any consequences. These arrangements shall include making known to the IAEA and to other States, directly or through the IAEA, the notifying State's designated organization(s) for so doing.

Arrangements shall be made for promptly and directly notifying any State within the emergency planning zones and emergency planning distances within which urgent protective actions and early protective actions and other response actions could be required to be taken.

Appropriate emergency response actions shall be initiated in a timely manner upon the receipt of a notification from another State or of information from the IAEA on a notification relating to an actual or potential transnational emergency that could have impacts on the State or its nationals.

Competent authorities and contact points for notifying of and reporting about a nuclear or radiological emergency

The Convention on Early Notification of a Nuclear Accident (the 'Early Notification Convention') and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (the 'Assistance Convention') are the prime legal instruments that establish an international framework to facilitate the exchange of information and the prompt provision of assistance in the event of a nuclear or radiological incident or emergency, with the aim of minimizing the consequences. The International Atomic Energy Agency (IAEA) has specific functions assigned to it under these Conventions.

The arrangements provided between the IAEA, the IAEA's Member States and/or Parties to one or both Conventions, all other relevant international intergovernmental organizations (herein referred to as international organizations), and other States for facilitating the implementation of these Conventions — specifically concerning those articles that are operational in nature — are documented in the present Operations Manual for Incident and Emergency Communication (IEComm)[2].

IEComm is the successor to the previous Emergency Notification and Assistance Technical Operations Manual (ENATOM), first issued on 18 January 1989. Member States, Parties to the Early Notification and Assistance Conventions, relevant international organizations and other States, have since then regularly received updates to the manual. This manual covers the communication protocols for Contact Points identified under the Early Notification and Assistance Conventions, as well as the protocol for users of the International Nuclear and Radiological Event Scale (INES).

In order to meet its legal responsibilities, the IAEA Secretariat needs to be prepared to respond appropriately and efficiently to any incident or emergency situation that may have actual or potential radiological consequences to health, property or the environment and which would urgently require the IAEA Secretariat's involvement. In addition, the IAEA Secretariat also needs to be in the position to respond to requests for assistance.

To address these issues, the IAEA established the **Incident and Emergency System (IES)** consisting of a 24-hour warning point5 and operational focal point in the Secretariat: the **IAEA's Incident and Emergency Centre (IEC)** which maintains a 24/7 alert and response capability. This capability can be used for requests for assistance and for urgent information exchange in situations that may give rise to radiological consequences, irrespective of their cause. States and relevant international organizations can promptly send or review information on radiation related events with potential or suspected consequences for the public. Media/public requests for information sent to the IEC are rerouted to the **IAEA's Division of Public Information (MTPI).**

Threshold of dissemination of information

The principles for when to exchange information and notify are specified in the IAEA Convention on early notification:

1. In case of a transnational emergency, see IAEA safety standards requirements (GS-R-2) and guides (IEComm).

Transnational emergency, as defined in the IAEA safety standards requirements, is a nuclear or radiological emergency of actual, potential or perceived radiological significance for more than one state. This includes:

- a significant transboundary release of radioactive material (however, a transnational emergency does not necessarily imply a significant transboundary release of radioactive material)
- a general emergency at a facility or other event that could result in a significant transboundary release (atmospheric or aquatic)
- discovery of the loss or illicit removal of a dangerous source that has been transported across or is suspected of having been transported across a national border
- an emergency resulting in significant disruption to international trade or travel
- an emergency warranting the taking of protective actions for foreign citizens or embassies in the state in which it occurs
- an emergency resulting in or potentially resulting in severe deterministic effects and involving a fault and/or problem (such as in equipment or software) that could have serious implications for international safety
- an emergency resulting in, or potentially resulting in, great concern among the population of more than one state owing to the actual or perceived radiological hazard.

[2] Operations manual for incident and emergency communications IAEA, Vienna, 2012 EPR-IECOMM, (2012).

2. In case of alert or advisory level communication

Alert level, in case of - an actual emergency exposure situation is being managed, and urget protective actions are being considered or implemented (i.e. evacuation, sheltering, issue of stable iodine)

- maximum permitted levels in food/animal feed are liable to be exceeded over an extended area
- abnormal significantly raised levels of radiation are measured in the environment (in the case of an event situated outside the Member State or of unknown origin)

In order to meet its legal responsibilities, the IAEA Secretariat needs to be prepared to respond appropriately and efficiently to any incident or emergency situation that may have actual or potential radiological consequences to health, property or the environment and which would urgently require the IAEA Secretariat's involvement. In addition, the IAEA Secretariat also needs to be in the position to respond to requests for assistance.

Advisory level

- cases of malicious or criminal use of radioactive material
- loss of theft of high-activity radiation sources or nuclear material
- unexpected finding of high-activity radiation sources or nuclear material
- events for which an INES level 3 (or more serious) notification is being considered
- transport incident involving radioactivity
- major radiation incidents in medical establishments, including unintended exposures in radiation therapy
- information necessary for rumour control, including any events (and nonevents) which receive excessive media coverage
- information necessary to the protection of the EU internal market (i.e. detection in customs of consumer goods not suitable for the market due to high level of radioactivity)

3. in case of

- an abnormal safety related event at a nuclear facility which could have offsite impact, or - detection of abnormal levels of fresh fallout, resulting in need for activating response or informing the public.

Concept of operations

The IES operates in three modes:

1. **Normal/Ready mode** – In Normal/Ready mode, the IEC is the focal point for incoming messages. It is not staffed continuously. On- call officers are available to immediately respond. This mode includes all day-to-day activities designed to ensure readiness and is the default condition in which the IEC is maintained. The IEC will remain in this mode through initial discussions of any incoming message regarding a situation with apparent, suspected or potential radiological consequences, particularly before the situation is confirmed. Assistance missions may be deployed in response to a request for assistance.
2. **Basic response mode** – In Basic response mode, the IEC is not staffed continuously. On-call officers remain available to immediately respond to incoming messages. If appropriate, some staff may be activated and additional staff may be placed on standby and preparations may be implemented to move rapidly to Full response mode. Extra assessments are made during office hours from staff activated by the IEC. Assistance missions may be deployed in response to a request for assistance.
3. **Full response mode** – In Full response mode the IEC is staffed continuously (24 hours a day with shift changes) and manages the IAEA's response actions.

Response actions and urgency of the response will vary according to the magnitude and potential consequences of the event.

Exchange of information

State Parties are obliged to send initial notification forthwith directly or through the IAEA to States which might be affected. Member States have the obligation to send a notification of transnational emergencies promptly. States are encouraged to send advisory messages of events directly or through the IAEA to States which might be affected. It should be noted that a transnational emergency is not necessarily transboundary.

For facilities close to national borders (when emergency planning zones go beyond national borders), a notification is expected to be sent directly (and to the IAEA) to the relevant neighbouring countries at the same time it is sent to the off-site authorities. Even when facilities are located far away from national borders, notifications are expected to be sent forthwith (i.e., within less than 2 hours) after the declaration of a nuclear or radiological emergency or when changes of the emergency class occur directly or through the IAEA. The IEC expects to receive initial information from a National Competent Authority (NCA).

This information will be authenticated and the message content verified with the NCA of the State that issued it. If the information is confirmed, the IES will be activated accordingly and the notification will be distributed to all Contact Points. The IEC distributes an initial notification **not later than 2 hours after** receiving it, while aiming at a much shorter response time.

The IEC may follow up with the NCA information received from Contact Points or from the INES national officers if the event warrants response.

The IEC rapidly screens follow-up information provided by the notifying State and, depending on its urgency:

1) sends it to NCA(A)s and Permanent Missions of other relevant States and relevant international organizations, as appropriate, and/or

2) posts it on USIE. Follow-up information has to contain all information important for minimizing the transboundary or transnational radiological consequences, which includes results from environmental radiation monitoring.

Contact Points are encouraged to send radiation monitoring data in editable electronic format (e.g., in the IRIX format) to the IEC. If information is received in another language but English, and if English translations will not be made available timely, the IEC makes an unofficial translation of the information and makes this unofficial translation available to other relevant States and international organizations with the consent of the State that provided the original information.

Follow-up information needs to be sent by the notifying State promptly **(i.e., not later than 4 hours)** after the notification of a nuclear or radiological emergency. For facilities close to national borders, it is expected that follow-up information is sent directly to neighbouring countries (and to the IAEA) at the same time as this information is made available to authorities at the national level.

Information with confidentiality marking, personal medical information or information whose distribution might pose a security risk will not be provided to Contact Points.

In addition, the IEC assesses and makes available information on the potential consequences of a nuclear or radiological emergency, including analysis of available information and prognosis of possible emergency progression based on evidence and scientific knowledge available to States and international organizations.

The relevant National Competent Authority or a State's Permanent Mission to the IAEA may request information about an on-going situation in another State. The IEC, after authenticating the request, will forward it to the relevant State that is expected to respond promptly to the IEC. The IEC, when appropriate, rapidly screens the reply for consistency, plausibility, legibility and comprehension and dispatches the response to the requesting National Competent Authority. However, if the situation is not confirmed, the IEC will inform the Contact Point that requested the information accordingly.

A request for assistance should be made as soon as it is determined that help will be needed from outs.de sources. To enable a potential assisting country to provide the most effective assistance, this request should be accompanied by an exchange of essential information. This information should include a description of the essential elements of the accident as far as it is known, the extent of the requesting State's current capability and the elements of support which might be needed.

Essentially, the areas of needs are those associated with:

(a) the nuclear installation itself or other sources of radiological emergency;

(b) the impact of the accident on the environment and the health and safety of the population; and

(c) the general problems associated with any major dlsastei or emergency.

On-site activities

On-site activities which may require assistance would generally consist of protective and corrective operations. These may include professional advice as well as working teams, specific materials and equipment, logistical aids and external facilities

In particular, it may be envisaged that expert profrssional advice by telecommunication links may be required at the early sta.e for helping in diagnosis of the problems, forecast of developments and choice of corrective actions. At a later stage, help may also be needed In reviewing the causes of the accident, which will be of value in assessing the damage to the plant and in planning appropriate recovery operations.

Highly qualified personnel would be required for radiation monitoring and other purposes. If radiation fields are high or the operations extended in time or scope, it may be necessary to make extra provisions for replacement of staff. The range of equipment and materials that may be needed could inlcude anything from survey-meters and protective equipment, or shielding materials, to sophisticated remote sensing devices and mechanical robots. It may include computing aids (hardward and software), general or highly specific components and replacement parts for the plant.

External facilities such as hospitals, counting and spectrometry laboratories, mechanical and electronic workshops would be involved in the general effort, and here again external assistance may be needed. It must be borne In mind that the activities associated with the plant itself may be quite prolonged, possibly extending over many months. Profession al aid in both expert manpower and equipment may be needed throughout this period.

Off-site activities

Also for off-site activities outside assistance may be requested. Such assistance may provide scientific advice and technical assistance to those who are faced with the requirement to monitor for radiation, provide for control of access and egress, provide personal protection methods, recommend evacuation, provide for decontamination, medical care, diversion of food and water supplies. Tiie assistance may take the form of a team of liighly skilled scientists and technical personnel actively involved in operations and research pertaining to nuclear radiation emergencies. The actual make-up of an assistance team will vary, reflecting the nature of the particular emergency situation and the assistance requested. The assistance may consist of personnel, technology and equipment according to the situation. The assistance team should, after approval, be prepared to move rapidly to the emergency site. In some cases, materials to be sampled would be sent from the site of the emergency to the laboratory of the assisting party.

Personnel required may Include: chemists, communications personnel, data analysts, engineers, health physicists, logisticians, medical personnel, meteorologists, photographers, nuclear physicists, physicians, biologists, pilots and ground crew.

Technology provided in the assistance team could include: aerial photography, chemical analysis, gamma ray spectral analysis, low level radiation detection, radiation intensity mapping, bloassay and techniques for radiation monitoring.

Equipment that could be made available as part of the assistance may include: airborne radiation detectors, aircraft (helicopters and fixed wing), communication systems, computers (field, portable and laboratory), groundborne and seaborne vehicles, handheld radiation detectors, whole-body counters, decontamination facilities, laboratory physical measurements equipment including sampling, navigation systems, mobile meteorological stations and general emergency relief equipment.

National warning point — NWP

The NWP role is assigned to a single institution in a State, which has been designated by its government to receive an initial notification/advisory/follow-up message and/or request for assistance, information or verification and immediately to act upon it on a 24/7 basis. The NWP's functions are independent of those of the NCA. Nevertheless, an NCA could also have the functions of an NWP.

The service is obligated, under the terms of the Early Notification and Assistance Conventions, to be available continuously, i.e. staffed and able to be alerted 24 hours per day, seven days per week. If requested to consider providing assistance, it needs to be able to rapidly forward any request received to the relevant NCA. The NWP must have persons on duty or have speedy access to persons who can understand and speak English. The NWP has a capability available at all times to receive fax messages and to establish direct telephone communications with the IEC.

Criteria for reporting the emergency

The categorization system adopted for the purpose of IEComm (Figure 4) addresses conditions:

1) specific to nuclear installations,
2) radiological events (not specific to nuclear installations), and
3) criminal or other unauthorized acts involving radioactive material.

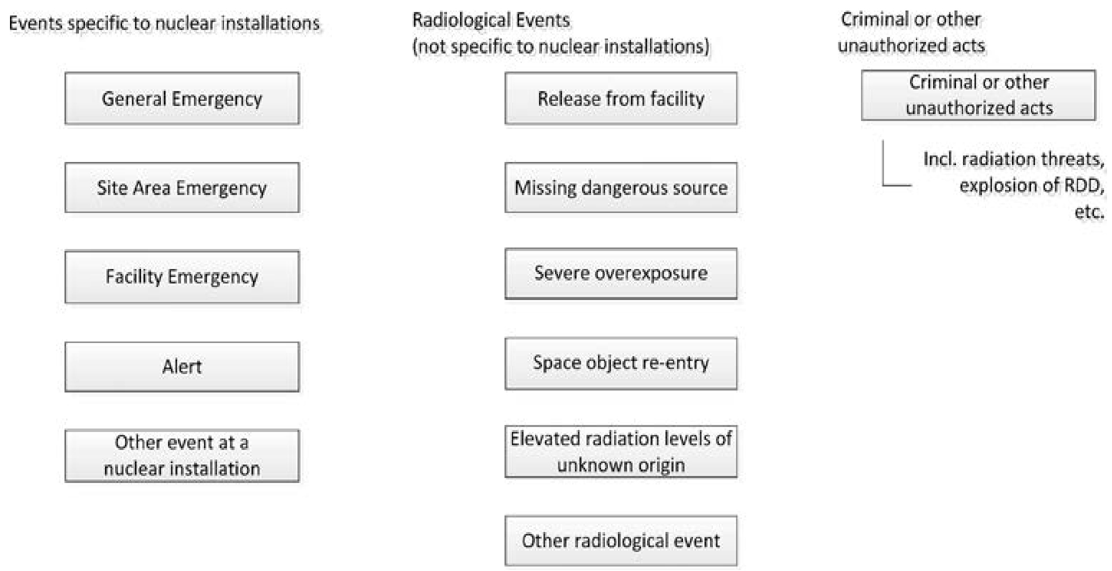

Figure 4. Sets of emergency conditions, grouped into three classes, used to describe situations that warrant immediate response actions under IEComm.

Events specific to nuclear installations

For events specific to nuclear installations, four classes are used to initiate different levels of actions, namely:

- «Alert»,
- «Facility Emergency»,
- «Site Area Emergency» and
- «General Emergency».

In addition, one procedure is given on how to provide information on other events in a nuclear installation that do not warrant a declaration of an emergency class. Such events may have to be communicated because of public or media interest, or if relevant lessons can be learned by the international community.

Radiological events (not specific to nuclear installations)

In addition to the classes that are specific to nuclear installations, there are six types of incidents or emergencies for which specific response procedures have been formulated, namely:

- «release from facility»,
- «missing dangerous source»;
- «space object re-entry»,
- «severe overexposure»,
- «elevated radiation levels of unknown origin» and
- «other radiological event».

IRIX report

A group of experts drafted an initial version of a new format, and it was given the name the International Radiological Information Exchange Format, or ‘the IRIX Format’ for short. In 2009, when the action plan concluded, a draft version of the IRIX Format had been developed. The IRIX report represents a message containing emergency related information and data, and/or requests for such information or data, sent from one organization to one or more other organizations.

The IRIX report has a set of metadata associated with it, including the name of the organization issuing the report, the date and time when the report was created, a unique identifier of the report, and so on. A total of 11 content sections have been defined in the IRIX Format.

Nine of the content sections represent the main class of content sections defined in the IRIX Format: the report sections. The report sections allow the inclusion of structured and semi- structured information on specific subjects of interest. The nine report sections are:

1 Event Information section;
2 Release Information section;
3 Meteorology section;
4 Consequences section;
5 Response Actions section;
6 Measurements section;
7 Medical Information section;
8 Media Information section;
9 Locations section.

Besides the report sections, there are two special content sections in the IRIX report: the Requests section and the Annexes section.

The Requests section allows the sending organization of the report to address requests for information to the recipient organizations of the report. The Requests section can also be used to return responses to such requests for information.

The Annexes section allows the inclusion of additional information in the form of attached files, or as free text annotations associated with any of the information sections or subjects of the report, and also cryptographic signatures.

International Radiation Monitoring Information System (IRMIS)

IRMIS is a web application that is continuously improved[3].

In the event of a nuclear or radiological emergency, the Convention on Early Notification of a Nuclear Accident requires the accident State to provide relevant information about the emergency situation. This should include information about the results of environmental monitoring relevant to

[3] «International Radiation Monitoring Information System». User Manual IRMIS Version 3.0.0, Emergency Preparedness and Response, EPR-IEComm, 2019.

the transboundary release of radioactive materials, and information about the off-site protective actions that have been taken or that are planned.

IRMIS has been developed to support the implementation of the Early Notification Convention, facilitating the reporting and visualization of large quantities of radiation monitoring data during nuclear or radiological incidents or emergencies. In addition, IRMIS supports and enhances some of the features of the Unified System for Information Exchange in Incidents and Emergencies (USIE).

USIE is a protected and secure web site that provides IAEA Competent Authorities (CAs) and points of contact designated under the Early Notification Convention with a unified communication tool through which they can share relevant information and data in a nuclear or radiological incident or emergency with the IAEA Secretariat, Member States and relevant international organizations.

Objectives of IRMIS

IRMIS assists IAEA Member States in meeting the requirements of the Early Notification Convention.

It complements USIE when a large quantity of radiation monitoring data needs to be shared and visualized. Thus, IRMIS enables near real time monitoring of the evolving radiological situation worldwide as a consequence of a nuclear or radiological emergency. IRMIS also aims to support the assessment of radiological hazards caused by the release of radioactive materials and facilitate the decision making process for protective actions on the part of any Member State impacted by a release and the provision of credible public information on the developing situation.

The application is fully functional in Internet Explorer 11 and Google Chrome on the Windows operating systems.

Radiological monitoring data

The radiological monitoring data in IRMIS are reported in either of two categories:

1. Routine Data, in the form of radiation dose rates from fixed monitoring stations voluntarily reported by participating Member States. The maximum or latest values reported per fixed station are displayed over the previous 24, 48 or 72 hours; or over user defined dates and times.

2. Emergency Data, collected during a nuclear or radiological emergency or on other occasions where the Member States deem it necessary to share radiation monitoring data with the IAEA and other Member States.

Routine Data

The routine provision, on a voluntary basis, of the radiation dose rate data from fixed monitoring stations in non-emergency situations is intended to ensure that the data can be reported effectively during an emergency. IRMIS provides a time series analysis tool which enables users to observe the systematic time correlated rise of dose rate data indicating a pre-release condition at a nuclear power plant. Thus, IRMIS provides a mechanism through which measurements recorded at the fixed monitoring stations can be reported in a timely manner during the early phase of an emergency. Routine Data are normally reported through an agreed arrangement where the organizations authorized to report these data will make them available in the International Radiological Information Exchange (IRIX) format on a secure data server hosted within their country, or via a regional hub (e.g. the European Radiological Data Exchange Platform (EURDEP)). IRMIS routinely retrieves radiation monitoring data from the servers: the web application gathers large amounts of data continuously with a periodicity of one hour. The maximum aggregated value of dose rate data over a number of spatially-close fixed monitoring stations is presented. The aggregated data correspond to either the maximum dose rate readings or the latest dose rate readings.

The type(s) of data, and the frequency and volume of Routine Data (as defined above) reported by Member States to IRMIS are at the discretion of the Member State and the IRMIS Data Provider(s).

Emergency Data

During an emergency, Member States may wish to provide additional data, for example: dose rate data collected through monitoring networks that do not routinely provide IRMIS with data, data from temporary fixed stations, data from hand held measurements or data from mobile monitoring systems (e.g. backpack, vehicle or aerial systems). Normally, these systems record dose rate measurements automatically, along with the location and time. Member States may, in certain circumstances, want to report event data that may not be of any safety significance, but nevertheless will provide situational awareness to neighbouring States. A web interface has been designed in IRMIS through which authorized users may upload the Emergency Data onto IRMIS, either in IRIX format or using a pre-formatted spreadsheet template. These Data Reports are subsequently reviewed and published on IRMIS by the IAEA's Incident and Emergency Centre (IEC).

Emergency Preparedness and Response Information Management System (EPRIMS)

The Emergency Preparedness and Response Information Management System (EPRIMS) is an interactive, web-based tool enabling Member States to self-assess their emergency preparedness and response (EPR) arrangements and to shareinformation on the results.

Assessing EPR arrangements on a national level is a complex task as emergency response

SELF-ASSESSMENT: Member States can use EPRIMS to assess their EPR arrangements against the IAEA safety standards and rate the extent to which each requirement has been met. Additional information can be entered separately for each emergency preparedness category to reflect differences in EPR arrangements between categories.

MULTI-USER ENTRY OF DATA: Multiple users can work with EPRIMS simultaneously, speeding up the self-assessment process. Country coordinators, national users and the IAEA cooperate during the self-assessment. The ability to register an unlimited number of national users ensures that a broad spectrum of EPR professionals can be involved.

INFORMATION SHARING: Member States can decide which countries have access to their information. This provides for closer regional and international EPR cooperation and allows countries to compare their arrangements with those of other States.

NEWSFEED: The EPRIMS home page features a newsfeed that notifies users when modules are added by other States that have chosen to share their data. Users can post announcements and comment on them.

REPORTS: Users of EPRIMS can quickly generate national reports based on information validated by each country. These can be used for example in preparation for events and meetings, or during training.

Unified System for Information Exchange in Incidents and Emergencies (USIE)

The IAEA Unified System for Information Exchange in Incidents and Emergencies (USIE) is a secure IAEA web site for Contact Points of States Parties to the Early Notification and Assistance Conventions and of IAEA Member States to exchange urgent information during nuclear or radiological incidents and emergencies irrespective of their cause (safety or security related), and for officially nominated INES National Officers to post information on events rated using the International Nuclear and Radiological Event Scale (INES). USIE offer encryption of information in transfer and storage and is monitored on a 24/7 basis.

TAKING MITIGATORY ACTIONS

Principal requirements on taking mitigatory action

Large nuclear accidents result when there are significant releases of radioactive material into the environment, impacting widespread areas and affecting extensive populations. They are unexpected events that profoundly affect individuals, society, and the environment. They generate complex situations and legitimate concerns, particularly regarding health, for all those affected by the presence of undesirable sources of radioactivity. Management of these situations requires the long-term mobilisation of considerable human and financial resources. Radiological protection, although indispensable, only represents one dimension of the contributions that need to be mobilised to cope with the issues facing all affected individuals and organisations.

For managing these events, the distinction between the early and intermediate phases of the accident, considered as emergency exposure situations, and the long-term phase, considered as an existing exposure situation.

The distinguishes between on-site and off-site to differentiate activities at the damaged installation and in the affected areas. The present recommendations may be applicable to other types of radiological emergencies, with due consideration of the differences that inevitably exist between a nuclear accident and these emergencies.

Characterisation of the radiological situation on-site and off-site is essential to guide protective actions, and should be conducted as quickly as possible to address the uncertainties regarding the intensity, duration, and extent of the radioactive contamination.

In emergency and existing exposure situations, the objectives of radiological protection are achieved using the fundamental principles of justification and optimisation. The principle of justification ensures that decisions regarding the implementation of protective actions result in a benefit for the affected people and the environment, as these actions can potentially induce significant disruption. The principle of optimisation of protection applied with reference levels aims to limit inequity in the distribution of individual exposures, and to maintain or reduce all exposures to as low as reasonably achievable, taking into account societal, environmental, and economic factors.

Justification and optimisation are applied in the mitigation of radiological consequences to people and the environment during all phases of the accident, and should take careful account of all non-radiological factors in order to preserve or restore the living and working conditions of all those affected, including decent lifestyles and livelihoods.

People involved in the direct management of the consequences of a nuclear accident are diverse in terms of their background, status, degree of preparation, and training on radiological protection. They include emergency teams (firefighters, police officers, medical personnel, etc.), workers (occupationally exposed or not), and other people such as elected representatives or citizens acting as volunteers. All these categories are considered as «responders». They deserve to be adequately protected and provided with suitable working conditions.

For the protection of responders on-site, the reference level during the early phase should not generally exceed 100 mSv, while recognising that higher levels, in the range of a few hundred millisieverts, may be permitted to responders in exceptional circumstances to save lives or to prevent further degradation at the facility leading to catastrophic conditions. Lower reference levels may be selected based on the situation, in accordance with the severity of the accident. During the intermediate phase, the reference level should not exceed 100 mSv. For the long-term phase, the reference level should not exceed 20 mSv per year, with possible special arrangements limited in time. Responsible organisations should take all practical actions to avoid unnecessary accumulation of exposures for responders involved in both the early and intermediate phases.

In some nuclear accident scenarios, release of radioactive iodine can result in high thyroid exposures due to inhalation or ingestion. Specific efforts should be made to avoid, or at least reduce, intakes of radioactive iodine, particularly in children and pregnant women. During the early phase or just after, exposed people should be monitored to detect potential exposure to radioactive iodine.

Management of the protection of people in affected areas in the intermediate and long-term phases is a complex process involving not only radiological factors, but also societal, environmental, and economic considerations. This process includes actions implemented by national and local authorities, and self-help protective actions taken by residents of the affected areas. In these phases, radiation exposures of people living and working in affected areas are largely dependent upon individual lifestyles. The authorities, experts, and stakeholders should co-operate in the so-called «co-expertise process» to share experience and information, promote involvement in local communities, and develop a practical radiological protection culture to enable people to make informed decisions. Individual measurements with suitable devices, together with relevant information, are very helpful in the implementation of this process.

For the protection of the environment, the recommends that fauna and flora should be protected using its framework based on Reference Animals and Plants, together with derived consideration reference levels. The impacts of protective actions on pets and livestock, as well as on the environment, in terms of sustainable development, conservation, preservation, and maintenance of biological diversity should also be addressed.

The plans should be prepared in advance to avoid severe and long-term consequences following a nuclear accident. Such preparedness plans should comprise a set of consistent protective actions, adapted to local conditions at nuclear sites, taking into account the societal, environmental, and economic factors that will affect the impact of the accident and its response.

First responders shall take all practicable and appropriate actions to minimize the consequences of a nuclear or radiological emergency involving a practice in threat category IV.

The operator of a facility or practice in threat category I, II, III or IV shall promptly take the actions necessary to minimize the consequences of a nuclear or radiological emergency involving a source or practice under the operator’s responsibility.

Emergency services shall be made available to support the response at facilities in threat category I, II or III.

Generic criteria are projected or received doses at which response actions are to be taken in a nuclear or radiological emergency (Table 6). The generic criteria are established at doses below those at which radiation induced health effects would be expected to be observed, even in a very large exposed group composed of the most sensitive members of the public (e.g. children and pregnant women). Therefore, while implementing response actions above those generic criteria would almost always be justified on radiation protection grounds, below these generic criteria response actions may not be justified on radiation protection grounds, requiring a special and careful consideration before their implementation. In all cases, regardless whether the projected or received doses are above or below the generic criteria, the response actions need to be justified (i.e. do more good than harm) and optimized, taking the overall protection strategy into account.

Projected or received doses cannot be directly measured or easily calculated early in an emergency when information is limited and uncertainties significant, and decisions need to be made quickly in order for the actions to be effective. Hence the need to develop operational criteria, such as OILs, that can be used directly in the response. If a response action is implemented soon enough, the majority of the projected dose can be averted and the risk of suffering severe deterministic effects or incurring an increased risk of stochastic effects significantly reduced.

Member States may decide to adopt the IAEA’s generic criteria directly or develop national generic criteria on the basis of the outcome of the justification and the optimization of their protection strategy.

Table 6

Generic criteria used as a basis for the OILs

Actions[a]	Generic criterion (GC)	Used for	References
Take response actions **under any circumstance** to avoid or minimize severe deterministic effects	**GC(Acute,AD$_{skin\text{-}ext}$,10h) = 10 Gy** RBE weighted absorbed dose to 100 cm^2 of the skin dermis of the representative person[b] from acute external exposure in the first 10 hours	OIL4$_{\gamma}$ OIL4$_{\beta}$	Table II.1 of Ref. [1]
Take **urgent** response actions to reduce the risk of stochastic effects	**GC(Urgent,E,7d) = 0.1 Sv** total[c] effective[d] dose to the representative person[b] in the first 7 days	OIL1$_{\gamma}$ OIL4$_{\gamma}$ OIL4$_{\beta}$	Table II.2 of Ref. [1]
	GC(Urgent,H$_{fetus}$,7d) = 0.1 Sv total[e] equivalent dose to the fetus[f] in the first 7 days	OIL1$_{\gamma}$ OIL4$_{\gamma}$ OIL4$_{\beta}$	Table II.2 of Ref. [1]
	GC(Urgent,h$_{thyroid,thy\text{-}burden}$) = 0.1 Sv[g] committed[h] equivalent dose to the thyroid from radioiodine in the thyroid (thyroid burden)	OIL8$_{\gamma}$	Ref. [1][i]
Take **early** response actions to reduce the risk of stochastic effects	**GC(Early,E,1a) = 0.1 Sv** total[c] effective[d] dose to the representative person[b] in the first year	OIL2$_{\gamma}$	Table II.2 of Ref. [1]
	GC(Early,H$_{fetus}$,9mo) = 0.1 Sv total[e] equivalent dose to the fetus[f] in the full period of in utero development	OIL2$_{\gamma}$	Table II.2 of Ref. [1]
Take response actions to reduce the risk of stochastic effects due to the **ingestion** of food, milk or drinking water	**GC(Ingestion,e$_{ing}$,1a) = 0.01 Sv[g]** committed[h] effective[d] dose to the representative person[b] from ingestion of food, milk and drinking water during the first year	OIL3$_{\gamma}$ OIL7	Table II.3. of Ref. [1]
	GC(Ingestion,h$_{fetus,ing}$,9mo) = 0.01 Sv[g] committed[h] equivalent dose to the fetus[f] from ingestion of food, milk and drinking water during the full period of in utero development	OIL3$_{\gamma}$ OIL7	Table II.3. of Ref. [1]

a Response actions are implemented based on projected doses. Received doses are used to identify those warranting medical actions to detect and effectively treat radiation induced health effects.

b The representative person is described in Section 3.4 Operational Intervention Levels for Reactor Emergencies and Methodology for Their Derivation OILs 2017.

c The total effective dose includes the effective dose from external exposure and the committed effective dose from intake of radioactive material during the exposure period in accordance with Table II.2 of GSR Part 7.

d Effective dose alone cannot be used to ensure that the doses to the specific organ may not exceed the threshold for severe deterministic effects resulting from intake (inhalation or ingestion) or radioactive material on the skin. However, keeping the projected equivalent dose to the fetus below 100 mSv for the exposure scenarios of interest will ensure that the RBE weighted dose from intake for any organ or tissue (including the fetus and the skin) will not exceed the generic criteria for severe deterministic effects, as listed in Table II.1 of GSR Part 7.

e The total equivalent dose to the fetus includes: a) the maximum committed equivalent dose to any organ from intake to the fetus for different chemical compounds and time relative to conception; and b) the equivalent dose to the fetus from external exposure during the exposure period, in accordance with Table II.2 of GSR Part 7.

f In this publication the term ‘fetus’ encompasses both the embryo and the fetus.

g For the notation of the dose, a lower case letter is used (i.e. e, h or ad) to indicate that only a single exposure pathway is considered, as opposed to the total dose from all relevant exposure pathways, for which an upper case letter is used (i.e. E, H or AD).

h For all committed doses addressed in this publication, the integration time given in the respective references is used, i.e. typically 50 a for the adult, 70 a for the infant and the period of in utero development for the fetus.

i The generic criterion of 50 mSv committed equivalent dose to the thyroid given in Table II.2 of GSR Part 7 was not used because it is intended for implementation of ITB and not for the urgent identification of those that may need medical follow-up. The criterion of 100 mSv committed equivalent dose to the thyroid for medical follow-up was determined based on consideration of: a) the equivalent dose to the fetus warranting medical follow-up as given in GSR Part 7 (i.e. 100 mSv); b) footnote e; c) the controlling organ dose to the fetus for intake of iodine being the thyroid; and d) the assumption that the equivalent dose to the pregnant woman’s thyroid is approximately equal to the equivalent dose to the fetal thyroid.

The use of OILs as part of the protection strategy for nuclear and radiological emergencies is required by IAEA Safety Standards Series No. GSR Part 7, and addressed by IAEA Safety Standards Series No. GSG-2 (Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency) and No. GS-G-2.1 (Arrangements for Preparedness for a Nuclear or Radiological Emergency), as well as by EPR Series publications (e.g. EPR-NPP Public Protective Actions 2013) and IAEA TECDOCs (e.g. IAEA-TECDOC-955).

OILs are operational criteria that allow the prompt implementation of protective actions and other response actions on the basis of monitoring results that are readily available during a nuclear or radiological emergency. ‘Operational’ refers to the need for the OILs to be practical and reflect the realities of the response to an emergency, such as the need for the measured quantities to be representative, easily measurable and readily available during a nuclear or radiological emergency.

A default OIL value is a specific value of such a measured quantity that indicates the need to implement predetermined response actions (e.g. evacuation, relocation, food restrictions). The response actions implemented based on the default OIL values are intended to minimize radiation induced health effects that would reduce quality of life.

The default OIL values provided in this publication follow a reasonably conservative approach; they are established below those levels at which radiation induced health effects will be observed, even in a very large exposed group of people composed of the most sensitive members of the public.

However, it is also important to consider non-radiological consequences of the response actions to ensure they do more good than harm. This is achieved by the justification and optimization of the overall protection strategy, as established in Requirement 5 of the GSR Part 7.

The default OIL values and methodology provided in this publication are generically justified and optimized on radiation protection grounds, but further optimization and justification may be necessary in consideration of the specific protection strategy in which the OILs will be applied. For example, using much lower default OIL values than those provided here could result in more harm than good when considering:

a) the health hazard associated with the response action itself; and

b) the diversion of limited resources from the highest priority actions.

By avoiding severe deterministic effects or a discernible increase in the incidence of stochastic effects (e.g. cancers).

Conservative meaning that it will result in a projected dose higher than the dose actually expected to be received under real conditions.

Default OIL values need to be developed during the preparedness stage,

a) to allow taking decisions on response actions quickly in the urgent and early phases of an emergency for the actions to be effective, and

b) to account for the limited availability and reliability of information at these phases of the emergency.

During past nuclear and radiological emergencies, failure to pre-establish default OIL values has resulted in unnecessarily postponing warranted response actions and in taking damaging actions that were not warranted based on the radiological health hazard.

Once actions have been completed based on the default operational criteria, and once the greatest risk to the public has therefore been alleviated, there will be time for more deliberate assessments. As the emergency progresses, further information may become available. Arrangements need to be established in advance to consider prevailing conditions as they evolve and, if justified, to revise the OILs and explain those changes to the public in a plain and understandable form.

Experience from past emergencies has shown that changing criteria for the implementation of response actions during an emergency may lead to confusion of decision makers and scepticism among the public.

Arrangements shall be made to provide expertise and services in radiation protection promptly to local officials and first responders responding to actual or potential emergencies involving practices in threat category IV. This shall include arrangements for on-call advice and arrangements to dispatch to the scene an emergency team that includes radiation specialists capable of assessing threats involving radioactive or fissile material[4], assessing radiological conditions, mitigating the radiological consequences and managing the exposure of responders.

These arrangements shall take into account the following aspects of the response to mitigate the consequences of a nuclear or radiological emergency: the operational actions necessary; the operational information needs; the workload and conditions of the operational staff (such as in the control room); the responder actions necessary in the facility; the conditions in the facility in which responder actions are necessary; and the response of the personnel, instrumentation and systems of the facility under emergency conditions. Arrangements shall include emergency operating procedures and guidance for the operator on mitigatory actions for severe conditions, for the full range of postulated emergencies, including accidents beyond the design basis.

The principal requirements on taking mitigatory action covered in the Safety Requirements publication[5] relate to:

Response

- the minimization by first responders of the consequences of an emergency in threat category IV;
- the minimization by the operator of a facility or practice in threat category I, II, III or IV of the consequences of an emergency;
- the provision of support by the emergency services to the response at facilities in threat category I, II, or III.

First responders shall take all practicable and appropriate actions to minimize the consequences of a nuclear or radiological emergency involving a practice in threat category IV.

The operator of a facility or practice in threat category I, II, III or IV shall promptly take the actions necessary to minimize the consequences of a nuclear or radiological emergency involving a source or practice under the operator's responsibility.

Emergency services shall be made available to support the response at facilities in threat category I, II or III.

Arrangements shall be made to provide expertise and services in radiation protection promptly to local officials and first responders responding to actual or potential emergencies involving practices in threat category IV. This shall include arrangements for on-call advice and arrangements to dispatch to the scene an emergency team that includes radiation specialists capable of assessing threats involving radioactive or fissile material, assessing radiological conditions, mitigating the radiological consequences and managing the exposure of responders.

In addition, arrangements shall be made to determine when additional assistance is necessary for dealing with radiological aspects and to obtain such assistance. First responders shall also be provided with guidance that is in accordance with international standards on the immediate response to actual or potential transport related emergencies and suspected illicit trafficking involving radioactive material.

The operator for a practice in threat category IV shall be given basic instruction in the means of mitigating the potential consequences of emergencies and promptly protecting workers and the public in the vicinity.

The operator for a practice using a dangerous source (such as practices in industrial radiography or radiotherapy) shall make arrangements to respond promptly to an emergency involving the source in order to mitigate any consequences. This response shall include prompt access to a radiological assessor or radiation protection officer who is trained and qualified to assess the emergency and to mitigate any consequences.

[4] This includes the possible use of such material for malicious purposes. An assessment of such threats could possibly be obtained through the IAEA under the terms of the Assistance Convention.

[5] Preparedness and Response for a Nuclear or Radiological Emergency, Safety Standards Series No. GS-R-2, IAEA, Vienna (2002).

Arrangements shall be made to initiate a prompt search and to issue a warning to the public in the event of a dangerous source being lost or illicitly removed and possibly being in the public domain.

For facilities in threat category I, II or III arrangements shall be made for mitigatory actions by the operator to prevent an escalation of the threat, to return the facility to a safe and stable state, to reduce the potential for releases of radioactive material or exposures and to mitigate the consequences of any actual releases or exposures.

The operating organization of a facility or activity in category I, II, III or IV shall promptly decide on and take actions on the site that are necessary to mitigate the consequences of a nuclear or radiological emergency involving a facility or an activity under its responsibility.

Off-site emergency services shall be made available for the purpose of, and shall be capable of, supporting the on-site emergency response at facilities and activities in category I, II, III or IV.

For facilities in category I, II or III, arrangements shall be made for mitigatory actions to be taken by the operating personnel, in particular:

(a) To prevent escalation of an emergency;

(b) To return the facility to a safe and stable state;

(c) To reduce the potential for, and to mitigate the consequences of, radioactive releases or exposures.

These arrangements shall take into account the full range of possible conditions affecting the emergency response, including those resulting from conditions in the facility and those resulting from impacts of postulated natural, human induced or other events and affecting regional infrastructure or affecting several facilities simultaneously. Arrangements shall include emergency operating procedures and guidance for operating personnel on mitigatory actions for severe conditions (for a nuclear power plant, as part of the accident management programme) and for the full range of postulated emergencies, including accidents that are not considered in the design and associated conditions. As far as practicable, the continued functionality of nuclear security system(s) needs to be considered in these arrangements.

The operating organization of a facility or activity in category I, II, III or IV shall assess and determine, at the preparedness stage, when and under what conditions assistance from off-site emergency services may need to be provided on the site, consistent with the hazard assessment and the protection strategy.

For facilities in category I, II or III, arrangements shall be made, in particular by the operating organization, to provide technical assistance to the operating personnel. On-site teams for mitigating the consequences of an emergency (e.g. damage control, firefighting) shall be available and shall be prepared to perform actions at the facility. Paragraph 5.15 of Safety of Nuclear Power Plants: Design (SSR-2/1) states that:

"Any equipment that is necessary for actions to be taken in manual response and recovery processes shall be placed at the most suitable location to ensure its availability at the time of need and to allow safe access to it under the environmental conditions anticipated."

The operating personnel directing mitigatory actions shall be provided with information and technical assistance to allow them to take actions effectively to mitigate the consequences of the emergency. Arrangements shall be made to obtain support promptly from the emergency services (e.g. law enforcement agencies, medical services and firefighting services) off the site. Off-site emergency services shall be afforded prompt access to the facility, and shall be informed of on-site conditions and provided with instructions and with means for protecting themselves as emergency workers.

Arrangements shall be made for the operating organization of an activity in category IV, first responders in an emergency at an unforeseen location, and those personnel at locations where there is a significant likelihood of encountering a dangerous source that is not under control to take promptly all practicable and appropriate actions to mitigate the consequences of a nuclear or radiological emergency. These arrangements shall include providing basic instructions and training in the means of mitigating the potential consequences of a nuclear or radiological emergency.

Arrangements shall be made to provide expertise and services in radiation protection promptly to local officials, first responders in an emergency at an unforeseen location and specialized services (e.g. law enforcement agencies) responding to emergencies involving activities and acts in category IV, and to those personnel at locations where there is a significant likelihood of encountering a dangerous source that is not under control.

This shall include arrangements for on-call advice or other appropriate mechanisms and arrangements to dispatch to the site an emergency team capable of assessing radiation hazards, mitigating radiological consequences and managing the exposure of emergency workers. In addition, arrangements shall be made to determine whether and when additional assistance is necessary and to determine how to obtain such assistance.

Arrangements shall be made to initiate a prompt search in the event that a dangerous source could possibly be in the public domain as a result of its loss or unauthorized removal.

These arrangements shall take into account the following aspects of the response to mitigate the consequences of a nuclear or radiological emergency: the operational actions necessary; the operational information needs; the workload and conditions of the operational staff (such as in the control room); the responder actions necessary in the facility; the conditions in the facility in which responder actions are necessary; and the response of the personnel, instrumentation and systems of the facility under emergency conditions. Arrangements shall include emergency operating procedures and guidance for the operator on mitigatory actions for severe conditions, for the full range of postulated emergencies, including accidents beyond the design basis

For facilities in threat category I, II or III arrangements shall be made to provide technical assistance to the operational staff. Teams for mitigating the consequences of an emergency (damage control, fire fighting) shall be available and shall be prepared to perform actions in the facility. “Any equipment necessary in… response and recovery… shall be placed at the most suitable location to ensure its ready availability at the time of need and to allow human access [to it] in the anticipated [emergency conditions or] environmental conditions.”

The personnel directing mitigatory actions shall be provided with an operating environment, information and technical assistance that allows them to take effective action to mitigate the consequences of the emergency. Arrangements shall be made to obtain support promptly from police, medical and fire fighting services off the site. Off-site support personnel shall be afforded prompt access to the facility and shall be informed of on-site conditions and the necessary protective actions.

Preparedness:

- the arrangements for the provision of expertise and services in radiation protection to local officials and first responders to an emergency in threat category IV, and for the provision of guidance to first responders on response to transport related emergencies and suspected illicit trafficking;
- for the operator of a practice in threat category IV, the provision of basic instruction in the means of mitigating the potential consequences of emergencies and protecting workers and the public;
- for the operator of a practice using a dangerous source, the arrangements to respond to an emergency involving the source, including prompt access to a radiological assessor or radiation protection officer;
- the arrangements for initiating a prompt search and to issue a warning in the event of a lost dangerous source;
- for operators of threat category I, II or III, the arrangements for mitigatory action to prevent escalation of the threat, to return to a safe and stable state, to reduce the potential for releases of radioactive material or exposures, and to mitigate the consequences of any actual releases or exposure;
- also for these same threat categories: the arrangements for the provision of technical assistance to the operational staff, for the availability of teams for mitigating the consequences, for

the location of equipment, for the personnel directing mitigatory actions, for obtaining support promptly from police, medical and fire fighting services off-site, and for access to the facility by, and the provision of information to, the off-site support personnel.

Observations

Emergencies by their very nature call for prompt response. Early recognition that an event has occurred is therefore essential, and this is covered in the previous subsection.

However, many of the emergencies that have been reviewed reveal that action was not taken as rapidly as necessary, even though it was realized that they were taking place. In some cases, staff within the facility were not prepared to perform their assigned emergency functions due to the hazardous conditions that were present (e.g. high radiation levels or temperature). In others, the procedures and training were ineffective because they did not address all plausible emergencies, could only be used after the underlying causes of the events had been diagnosed[6], or did not consider the response of systems or instrumentation under emergency conditions[7]. These procedural and training deficiencies occurred even though the high hazard conditions were a logical implication of postulated emergencies.

In some emergencies within facilities, assistance by off-site organizations was delayed because there were no provisions for giving them prompt access, the information on what to expect upon arrival, or appropriate radiological precautions to take. For example, many local firemen responded to the Chernobyl accident within the first few hours. However, they did not have sufficient training and adequate personal protection, which contributed to the formation of high doses for them.

In most scenarios, relocation decisions will be based on doses from external exposure to the whole body from deposited radioactive materials and internal exposure from inhalation of resuspended deposited material.

Other protective actions, such as simple dose reduction techniques, can be applied in areas where levels of deposited radioactivity are not high enough to warrant relocation. Dose reduction actions can range from the simple – scrubbing or flushing surfaces, removal and disposal of small spots of highly contaminated soil (e.g., from settlement of water), and spending more time than usual in lower exposure rate areas (e.g., indoors) – to the difficult and time consuming processes of removal, disposal and replacement of contaminated surfaces. The simple processes would probably be most appropriate in contaminated areas outside the relocation area. Many of these can be carried out by the residents with support from officials for monitoring and guidance on appropriate actions and disposal. The more difficult processes will be appropriate for recovery of areas where contamination is fixed (not removable) and from which the population is relocated.

Access to and/or activities within large areas may have to be restricted. As the land area increases, protective actions become more difficult and costly to implement, especially when the affected area is densely populated. There may be situations where full implementation of early and intermediate phase protective actions is impracticable (e.g., a release in a large city). Informed judgment must be exercised to assure priority of protection for individuals in areas having the highest exposure rates.

The Population Affected

The relocation have been established at a level that will provide adequate protection for the general population, including higher risk groups such as children and fetuses. People residing in contaminated areas outside the relocation area will be at some risk from radiation dose. Therefore, guidance on the reduction of dose during the first year to residents outside this zone is also provided.

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[6] Legasov V. Testament by First Deputy Director of the Kurchatov Institute of Atomic Energy, Moscow, as published by Pravda 20 May 1988, , translation taken from MOULD, R. F., Chernobyl Record: The Definitive History of the Chernobyl Catastrophe, Bristol, Institute of Physics Publishing (2000).

[7] Lessons Learned from Accidents in Industrial Radiography, Safety Reports Series No. 7, IAEA, Vienna (1998).

Monitoring and simple dose reduction efforts are recommended in these areas to reduce doses to the extent practical. Such actions are unlikely to be practical where the dose reduction achieved is less than 10 percent.

Affected populations may perceive that intermediate phase protective actions are not consistent with those taken in the early phase. Early-phase decisions on sheltering-in-place and evacuation may have been implemented prior to verification of the path of the plume. Therefore, some people may have been evacuated from areas where validated doses are much lower than were projected. Others who were in the path of the plume may have been sheltered or not protected at all.

During the intermediate phase of the response, dose projections may be revised based on environmental measurements. People should be relocated from areas where the projected dose exceeds the norm`s for relocation without regard to prior evacuation status.

Areas Involved

Figure 5 provides a generalized example of the areas affected by different protective actions. Area 1 represents the plume deposition area. (In reality, variations in meteorological conditions would almost certainly produce a more complicated shape, but the same principles would apply.)

In situations such as an NPP accident, where early warning is given prior to a release of radioactive materials, people may already have been evacuated from Area 2 and sheltered in Area 3. People who have been evacuated from Area 2 or sheltered in Area 3 may go home if environmental monitoring verifies that their residences are outside the plume deposition area (Area 1).

Area 4 is the relocation area where projected doses are equal to or greater than the relocation norm`s. People residing just outside the boundary of the relocation area may receive a dose approaching the norm`s for relocation if decontamination or other dose reduction efforts are not implemented.

Area 1, with the exception of the relocation area, represents the area of contamination that may continue to be occupied by the general public during the intermediate phase. Nevertheless, there will be contamination levels in this area that will require continued monitoring and dose reduction efforts other than relocation. Incident-specific levels below the norm`s may be used to control exposure to contamination. The relative positions of the boundaries shown in Fig. 5 depend on areas evacuated and sheltered and the radiological and meteorological characteristics of the release. For example, Area 4 (the relocation area) could fall entirely inside Area 2 (area evacuated), so that the only people to be relocated would be those residing in Area 4 who were either missed in the evacuation process or who, because of mobility constraints for their evacuation, had remained sheltered-in-place during plume passage.

Establishing the boundary of a relocation area creates three groups of affected people—

People who have already been evacuated from an area that is now designated as a relocation area and who now must be assigned relocation status.

People who were not previously evacuated, but who reside inside the relocation area and should now relocate.

People who were previously evacuated, but reside outside the relocation area and may now return home. A staged and deliberate return is recommended.

Small adjustments to the boundary of the relocation area established based on the norm`s may be justified based on ease of implementation. For example, the use of a convenient natural boundary could be a logical reason for adjustment of the relocation area. However, such decisions should be supported by demonstration that exposure rates to people not relocated can be promptly reduced by methods other than relocation to meet the norm`s, as well as the longer-term dose guidelines.

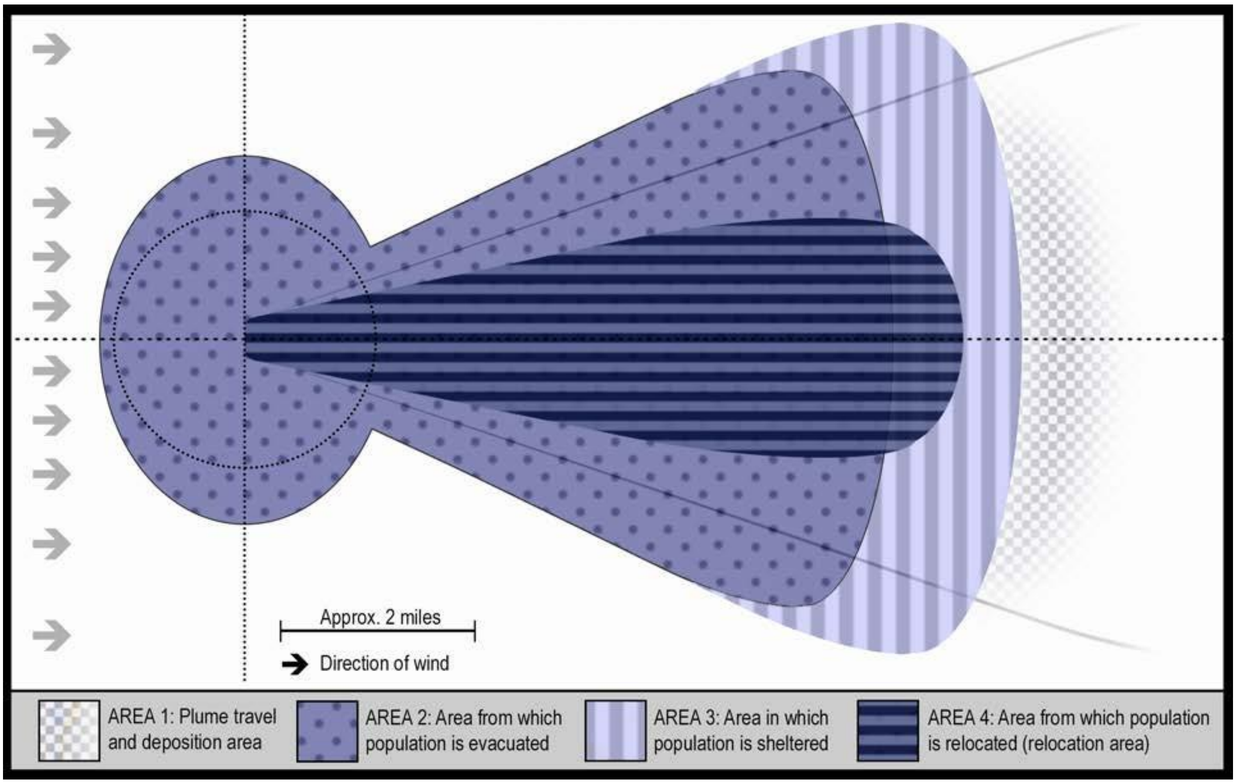


Fig. 5. Generalized Protective Action Areas for NPP Incident

The relocation PAGs apply principally to personal residences but may impact other facilities as well. For example, it could impact work locations, hospitals and parklands as well as the use of highways and other transportation facilities. For each type of facility, the occupancy time of individuals should be taken into account to determine the criteria for using a facility or area. It might be necessary to avoid continuous use of homes in an area because radiation levels are too high. However, a factory or office building in the same area could be used because occupancy times are shorter. Similarly, a highway could be used at higher contamination levels because the exposure time of highway users would be considerably less than the time spent at home.

Planning and Taking Action

In order to determine whether a protective action should be implemented, authorities will need to establish a relationship between the measured concentration of one or more radionuclides in finished drinking water and the radiation dose members of the population might experience as a result of drinking contaminated water.

Incident-specific factors that may be taken into consideration include:

1. The particular radionuclides being emitted in this emergency situation
2. The rate and timing of entry of the radionuclides into the drinking water supply, via atmospheric deposition or by other means
3. The rate of natural attenuation of the radionuclides
4. The estimated potential duration of public exposure to contaminated drinking water
5. The estimated daily consumption of contaminated drinking water.

Those responsible for implementing protective actions will need to convert values into OILs in units of Bq/L or pCi/L for each radionuclide of interest.

There are specific radionuclides, including cesium-137 (Cs-137), iodine-131 (I-131) and strontium/yttrium-90 (Sr-90/Y-90) that are of particular interest for major radiological incident scenarios where drinking water sources might be contaminated. In annex presents default OILs for these radionuclides to aid emergency managers in making water restriction decisions involving these contaminants.

State and/or local authorities and drinking water utilities can take to protect the public in the event that a water supply is affected by a nationally significant radiological contamination incident.

Preventive action, such as temporary closure of water system intake valves to prevent a contaminant plume from entering the system, may be taken in advance of an anticipated release; it is not necessary to wait until drinking water contamination is detected. Emergency response plans need to consider whether sufficient storage capacity is available to support the community's fire suppression and sanitation needs while the intake valves are closed.

Emergency planning provides the opportunity to develop state, local and utility-specific plans and implementation procedures that reflect the unique needs of a particular community. Advance planning can provide clarity and facilitate the decision-making process during a radiological emergency.

After deposition has ended, radionuclide concentrations present in a water supply may decline at rates determined by the half-lives of the individual nuclides, may decline faster by dilution with uncontaminated water, or may even increase after rainfall and seasonal thaw events in an affected watershed. The concentration of radionuclides in drinking water as a function of time after the incident can be measured, estimated or modeled based on knowledge of the incident, including radionuclide sources and the properties of the drinking water supply. Models and estimates should be validated by monitoring or sampling

Unlike naturally-occurring radionuclide contamination of drinking water from minerals present in geological formations, for a radiation release incident, ground water sources are expected to be less vulnerable to contamination than surface water sources, but this should be confirmed by monitoring or sampling. The potential for ground water to become contaminated will greatly depend on whether the ground water resource is close to the surface or is from a deep aquifer bounded by an aquitard, as well as on rainfall rate and the composition of the overlying soil (which will affect the rate at which contaminants deposited on soil will migrate to the ground water resource).

Below discusses actions that authorities can take to minimize radiation doses from drinking water. Because radionuclides decay over time, early interventions such as restricting use of contaminated water immediately after the incident may be most effective in reducing radiation dose to the population. Such decisions may need to be made based on limited information. Authorities may find it prudent to take such action even before field sample measurements or modeled estimates of radiation dose have been calculated and validated.

Monitoring and Characterization of Contaminants

A comprehensive radiological surveillance program to monitor concentrations of radionuclides of interest in both source water (including both upstream and downstream of intakes, as applicable) and finished drinking water would provide an indication of whether any adjustments are necessary or if the actions being taken are effective.

The standarts requires community water systems (CWSs) to conduct monitoring at each entry point to the distribution system to ensure that every customer's water does not exceed the reference level radionuclides.

All CWSs are required to monitor for gross alpha, radium-226/228, and uranium. In addition, CWSs designated by the state as "vulnerable" and those using waters "contaminated" by effluents from nuclear facilities must also conduct monitoring for beta particle and photon radioactivity. If a water system is directed by the primacy agency to collect samples for compliance purposes, approved analytical methods must be used.

In the event of a radiological contamination incident, state officials may require public water systems to immediately collect additional samples for radionuclides, including beta particle and photon activity.

However, during an emergency situation it may be necessary to identify alternative sampling and analytical approaches to obtain data to inform short-term actions by emergency response personnel. Many States have established Radiological Emergency Preparedness programs designed to guide sample collection and analysis and to advise emergency managers in a radiological emergency.

Additionally, State can deploy monitoring and sampling field teams and provide dose assessment expertise to assist states and local communities in responding to an emergency.

Samples should be collected from entry points to the distribution system. Challenges may arise from variability in environmental matrices. Advance emergency planning can help to achieve sample representativeness and homogeneity relative to routine samples.

Once the situation is better characterized and systems are working towards returning to compliance, monitoring should be conducted at entry points to the distribution system using only approved analytical compliance methods.

If members of the public are served by drinking water from household cisterns or private wells, local officials should consider how monitoring should be undertaken to determine levels of target radionuclides and assess the risks posed to these populations.

Public Notification

An emergency response plan should include a strategy for keeping the community informed of the actions being taken by authorities and clearly delineate roles and responsibilities of local officials and emergency responders. This includes communicating to customers of CWSs and (if applicable) to those who rely on household cisterns and private wells. It is critical for water utilities to participate in the emergency response planning activities.

For example in USA: If compliance monitoring indicates that contamination levels exceed the level for any radionuclide, water systems are required to issue public notice on a “Tier 2” time frame (i.e., as soon as practical, but no later than 30 days after the system learns of the violation). CWSs should be able to issue repeat notices as required. However, states may determine that the notification requirement should be elevated to a “Tier 1” Public Notification (i.e., as soon as practical, but no later than 24 hours) based on a significant potential for serious adverse effects on human health due to short-term exposure.

During a response to a major radiological incident, water systems may have difficulty with issuing public notifications in addition to managing the response to the contamination event. The state may issue public notification on behalf of the water system.

This would allow the state to deliver a consistent message to all affected customers and allow the system to concentrate its efforts on returning to operation or returning to compliance in the event of rise the level of radionuclide(s).

State and local authorities should be proactive in communicating about risks and uncertainties and providing clear instructions to the public.

Additional Actions to Reduce Levels of Contamination

In the initial phase following a radiological incident, officials should take reasonable precautionary measures (i.e., closing intake valves) to protect water sources as soon as notification of a radiological release or impending release is received.

Moving into the intermediate phase, as data are obtained from monitoring programs (including sampling and analysis of water upstream and downstream of a water system intake structure and within the distribution system), officials should benchmark observed concentrations against the default that account for specific isotopes present, release patterns, and decay. Officials would then be in a position to make informed decisions about the need to implement protective actions. Water system officials should be in close communication with their drinking water regulatory agency (e.g., state) prior to taking protective actions.

Options available to water systems to reduce radiation dose to drinking water customers include applying treatment technologies, relying on back-up storage, blending water, accessing alternative water sources, and rationing of uncontaminated water or a combination of these actions. Examples of these options are described briefly below. Technical and economic burden on smaller systems may be reduced by pooling resources with other water systems (e.g., establishing interconnections, sharing technical and operator staff, and sharing of supplies and equipment). As part of emergency planning efforts, local officials should consider the possibility of temporary rationing of uncontaminated or treated water if supplies are inadequate to meet normal demand.

All of these options require advanced planning and should be evaluated and included in state plans as appropriate (Guidance on developing emergency drinking water supplies).

Treating Contaminated Water

Systems with the appropriate technology in place can treat contaminated water to reduce elevated radionuclide levels. Four treatment technologies are classified by EPA as Best Available Technologies (BATs) for removing radionuclides from drinking water: coagulation/filtration, ion exchange, lime softening and reverse osmosis. EPA has also listed these BATs as Small System Compliance Technologies (SSCTs) for radionuclide’s treatment, along with less commonly used techniques such as green sand filtration, co-precipitation with barium sulfate, electrodialysis/electrodialysis reversal, pre-formed hydrous manganese oxide filtration and activated alumina.

Removal efficiency for specific radionuclide’s will vary across available technologies and may depend on technology-specific parameters (e.g., ion exchange effectiveness depends on pH, resin selected and presence of other ions). In addition, liquid and solid treatment residuals with elevated radiation levels may have special disposal requirements. Disposal options may vary from one jurisdiction to another, and may depend on the type, concentration and volume of residuals. Further information on residual disposal considerations is available from standards.

Temporarily Closing Intake Valves

If the deposition of radionuclide’s into a river is limited in duration, only a portion of the water may become contaminated. A water system with enough storage capacity can temporarily close its intake valves and allow the contaminants to flow past the intake to prevent contamination from entering the distribution system. If stored water supplies are not sufficient to meet community fire suppression and sanitation needs while intake valves are closed, the system could take other actions discussed in this section, including supplementing water supplies with alternate sources or implementing water use restrictions.

Establishing Interconnections to Neighboring Systems

If the water system is part of a larger, regional supply system, existing interconnections to uncontaminated neighboring water supplies could be activated. It might also be possible to construct temporary pipelines on an impromptu basis. If this option is implemented, steps should be taken to prevent backflow from the contaminated system. Care will also need to be taken to ensure that the supply of water and treatment capacity at the uncontaminated system will adequately serve the larger population.

Blending Water Sources

If a source of uncontaminated water is available, a water system may choose to blend water from contaminated and uncontaminated sources of drinking water to minimize radiation doses from drinking water. The water may be blended using storage tanks or a common header to allow for complete mixing prior to distribution to customers.

Importing Water in Tanker Trucks

Under some circumstances (e.g., difficult terrain, urgent need), it may be more efficient or expedient to temporarily transport clean water by truck, rail or barge to distribution centers in the affected community than to lay down pipelines. State and local departments of public health, as well as emergency management agencies, typically have standards and requirements related to hauling water. Water systems would benefit from having procedures for importing water in tanker trucks documented in an emergency response plan. All water systems importing water by tanker should verify that their plan adheres to state and local requirements. If the water system's distribution system is not being used to provide the imported water, the needs of residents with limited transportation options and physical disabilities should be taken into account when selecting locations for distribution centers. The availability of suitable transport vehicles may limit use of this option.

Importing Bottled Water

Providing bottled water to the affected community is another possible option during an emergency situation. The water may come from a nearby water system or from a water bottling company. This option may be cost-effective during an emergency if water is needed quickly and if the length of the emergency does not require long-term action, such as the construction of an interconnecting pipe.

Response Levels

Once the incident characteristics have been assessed, information regarding duration of the radiological release and the half-life of nuclides involved as well as other factors may be considered by local decision makers in projecting doses and adapting mitigation measures. All radionuclides are covered by the assessment tools provided by emergency servis. For instance, if an alpha emitting isotope was of concern following a radiation contamination incident, it would be included in any calculations regarding protective actions for drinking water. As such, local officials may choose to work with emergency servisies to calculate situation-specific OILs that are based on information gained during the intermediate phase, including identification of specific isotopes, release patterns, and associated decay functions.

In the unlikely scenario where radioactive isotopes are continuously replenished, recommends using the conservative assumption that radionuclide levels will remain constant over the course of one year. Such an assumption provides an added level of protection in light of the many unknowns involved in an emergency. In fact, after the initial deposition event has occurred, concentrations usually decline at rates determined by the half-lives of individual isotopes, or decline faster due to dilution with uncontaminated water, or could even increase after rainfall or subsequent deposition events. Some nuclides, like I-131, have half-lives measured in days, while others, like Cs-137, have half-lives measured in years.

Table 7 provides default levels for those unlikely scenarios. These default levels provide for convenience to allow local entities to make quick decisions about drinking water provided by public water systems in the event of a radiological emergency.

Early exceedance of the default levels does not suggest that doses will stay at that level. In most cases, levels will drop below protection actions as radionuclide concentrations in water decline by a combination of radioactive decay and natural attenuation. If the concentrations of radionuclides do not exceed levels over the course of one year, doses will remain below the requirement protection actions.

Table 7

Default response levels – Drinking Water Concentrations Corresponding to Specified Doses (mrem) of Select Radionuclides, Assuming One Year of Exposure at Constant Levels

Isotope	DRLs for pregnant women, nursing women and children age 15 and younger – 100 mrem dose	DRLs for the general population – 500 mrem dose
Sr-90/Y-90[54]	1,000 pCi/L	7,400 pCi/L
Cs-137	6,200 pCi/L	17,000 pCi/L
I-131	820 pCi/L	10,000 pCi/L

The provided in Table were derived by calculating life-stage-specific for eight different ages (fetus, breastfed infant, infant, 1, 5, 10, 15, and adults). For the most sensitive life-stages, concentrations of individual radionuclides yielding a 100 mrem dose were calculated for each age group, then the most protective/lowest radioactivity concentration was selected as the threshold values for the entire sensitive life-stage group, including pregnant and nursing women. The calculated values differ across individual life-stages because each age group has a different dose conversion factor and drinking water ingestion rates.

The values in Table indicate the concentration of each radionuclide which results in the corresponding radiation dose value if such radionuclide was the radiation emitter in drinking water. Values provided in this table have been rounded to two significant figures. The calculated values provided in Table are intended to illustrate the methodology and conservative assumptions believes are adequate to provide a reasonable level of protection to sensitive populations.

Y-90 is a radioactive decay product of Sr-90 and will normally be found alongside Sr-90 in the case of a Sr-90 release; therefore, they are treated together. Solubility differences may cause less yttrium to be present; however, it is a conservative assumption to include both in table.

Factors considered when establishing the drinking water ptotection action levels

The purpose of the protective action for the drinking water exposure pathway is to restrict the use of contaminated water for drinking and to provide recommendations for local communities to consider in providing alternative drinking water for the affected community during a nationally significant radiological incident, such as a disaster at a nuclear power plant, an RDD or an IDD. The drinking water limitations apply during the intermediate phase of an incident, which may last for weeks to months but not longer than one year.

Protection action is based on three principles:

1. Prevent acute effects.
2. Balance protection with other important factors and ensure that actions result in more benefit than harm.
3. Reduce risk of chronic effects.

Specifically, consideration was given to the acute effects of exposure to radiation and lifetime risk of cancer based on age and drinking water intake.

The drinking water Protection action was developed based on reducing risks associated with ingesting drinking water contaminated with radionuclides. Also considered the potential radiation dose people could receive from various other uses of contaminated water, including showering, bathing, and dishwashing.

In the United States, for example, people typically shower, bathe, and wash dishes using the same source of water that they use to drink, but, for the radionuclides of interest, dermal and inhalation exposures from these activities generally represent much smaller risk than drinking contaminated water. Protection of a community's drinking water supply based on assumptions about ingestion will also protect the population from undue risk from contaminated drinking water by other routes of exposure.

Reentry matrix following a radiological incident or accident

During the intermediate phase, people will need to enter the relocation area to collect their belongings, maintain or repair critical infrastructure, and to work on preliminary recovery activities. The Reentry Matrix in Table 8 provides a quick reference for public and worker dose guidelines and considerations for decontamination ongoing during this phase.

The Operational Guidelines are informative for this guidance, specifically the discussions about applicable dose-based limits, timeframes and pathways of exposure related to reentry tasks.

The term reentry is used for emergency workers and members of the public going into radiologically contaminated areas, temporarily, under controlled conditions. Food and agriculture guides use methods and models for implementation, which allow derivation of decontamination thresholds for the early and intermediate stages of a response.

As part of the U.S. response to the Japanese Fukushima accident, scientists performed dose calculations to ensure that passengers and workers on train trips through contaminated areas do not exceed doses typically received from cosmic radiation during an international flight. DOE's Argonne National Laboratory scientists utilized the RESRAD-RDD tool and hand calculations to approximate doses from the NPP radionuclides.

Taking agricultural countermeasures, countermeasures against ingestion and longer term protective actions

The principal requirements on taking agricultural countermeasures, countermeasures against ingestion and longer term protective actions covered in the Safety Requirements publication [GS-R-2] relate to:

Response

- the taking of agricultural countermeasures and longer term protective actions;
- the appropriate management of radioactive waste and contamination;
- the discontinuance of a protective action.

Preparedness

- the establishment of optimized intervention levels and actions levels;
- for areas with activities in threat category V, the arrangements for taking agricultural countermeasures;
- for a major release of radioactive material from a facility in threat category I or II, the arrangements for temporary relocation;
- for the emergency zones, the arrangements for monitoring vehicles to control the spread of contamination;
- the arrangements for the management of radioactive waste;
- the arrangements to assess the exposures of the public and to make the information publicly available.

Observations

Following an accidental release of radioactive material into the atmosphere from a facility in threat category I or II, protective actions relating to the consumption of foodstuffs produced in the path of the plume may be necessary. The prevention of the consumption of contaminated milk is usually the most urgent, but other foodstuffs also need to be considered in the relatively short term, particularly leafy vegetables. Protective actions regarding the consumption of food that may be contaminated within months, such as meat, should also be instituted on a somewhat longer timescale. As the Chernobyl accident has demonstrated, such countermeasures may need to be extended out to considerable distances from the site of the accident, covering very large areas, which require extensive environmental monitoring.

Table 8

Reentry Matrix: Quick Reference to Operational Guidelines

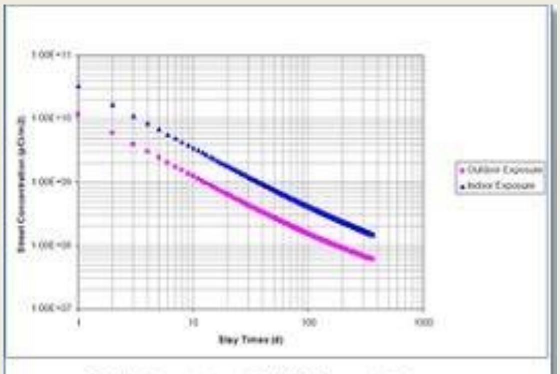
PHASE	ACTIVITY	SUGGESTED LEVELS	CLEANUP ACTIONS
Early Phase	**Sheltering or Evacuation for the Public**	**Public**: 1-5 rem (10-50 mSv) projected over four days (see Chapter 2). A decision to evacuate weighs anticipated dose against feasibility of evacuating within a determined time frame, along with the risks associated with the evacuation itself.	It is too early for organized cleanup, due to chaos of the situation and higher priorities such as lifesaving activities and clearly identifying shelter and evacuation zones. Any cleanup or decontamination information should focus on personal decontamination. It is doubtful any large-scale effort could change evacuation or shelter recommendations during this period (first 4 days). Once evacuation is completed, there are simple actions that cities can implement themselves: rinsing roofs and streets, street sweeping. The objective of these actions is to move the bulk amounts of contamination away from occupied areas or areas where reoccupation is a priority. These actions should be based on measured amounts of contamination and priority of the location. Workers may face high dose levels and will need health physics support.
	Emergency Worker Protection	**Emergency Worker**: 5/10/25 rem (50/100/250 mSv) incurred over the response duration. The higher limits are based on task (e.g., protecting large populations or critical infrastructure or lifesaving). Emergency worker doses will be tracked with dosimeters. Emergency workers have knowledge of the risks associated with radiation exposure, training to protect themselves, and dosimeters to track their doses	
Inter-mediate Phase	**Relocationfor the Public**	**Public**: 2 rem (20 mSv) projected first year, 0.5 rem (5 mSv) per year projected in subsequent years In this phase, scientists run dose calculations; the user can choose sensitive age groups, or enter lower guidelines, if desired. Additionally, local decision-makers can adapt the guidelines with incident-specific considerations and implement variations as needed.	Early cleanup efforts should focus on the removable portion of the contamination: vacuuming, washing, vegetation removal. ▪ Vacuuming has the advantage of collecting removable contamination without water or surface impact, but is limited by equipment availability and can also expose the operators to high dose levels as the vacuums collect the contamination. ▪ Washing and rinsing are simple to implement, but only move the contamination to less-populated areas and may move contamination deeper into porous surfaces. ▪ For unpaved areas, vegetation removal can effectively reduce the amount of contamination present, but is labor intensive and can produce a large amount of waste.
Inter-mediate Phase	**Reentry For Use ofCritical Infra-structure**	**Public**: 2 rem (20 mSv) in first year. Dosimeters could be considered for the public.	Having addressed the removable part of the contamination, later efforts can focus on fixed contamination. ▪ Paved surface removal is very effective, but requires specialized equipment and trained operators. ▪ Surface sealing is easier, but leaves the contamination in place, making it viable only in locations where the dose rates are low enough for occupation, or in low- occupancy areas. ▪ Repaving roads, lots and other paved surfaces is easy to implement, but cangenerate significant waste volumes. ▪ Unpaved areas can be further remediated by soil skimming (surface removal), deep plowing (turning the top foot or so of soil over), and appropriate chemical soil amendment methods like liming or chelating.
	Emergency Worker Protection	**Emergency Worker Protection**: (dose not to exceed) 5 rem (50 mSv) per year Emergency workers have knowledge of the risks associated with radiation exposure, training to protect themselves, and dosimeters to track their doses	

<table>
<tr>
<td rowspan="2"></td>
<td></td>
<td>During an incident response, workers (police, waste handlers) needed in contaminated areas could be trained and given dosimeters. The guidance for emergency workers applies throughout the response.</td>
<td rowspan="2">As the intermediate phase progresses, knowledge and experience increases and these methods can be re-applied, refined or customized for problem areas. Decisions about more difficult areas will benefit from professional judgment, additional analyses, and application of more sophisticated technologies.</td>
</tr>
<tr>
<td>Reentry For Use ofRoads andWalkways</td>
<td>Public: 2 rem (20 mSv) first year, 0.5 rem (5 mSv) per year in subsequent years
While the dose values here are similar to those for Use of Critical Infrastructure above, the derived concentrations measured as triggers are different because the exposure conditions are different.</td>
</tr>
<tr>
<td>Inter-mediate Phase</td>
<td>Reentry
For Access to the Relocation Zone

"Stay time" is a term of art used in the radiation safety field. Stay times are the amount of time a person may access the contaminated area. These times vary based upon site-specific factors or incident character-istics such as indoor or outdoor work, sensitive populations, and level of radioactivity.</td>
<td>Public: 0.5 rem (5 mSv) over one year for temporary access with stay times dependent on reentry tasks and site-specific conditions

Guidelines provides tables and graphs of stay times at various limiting concentrations (see adjacent graph and table). For example, if the maximum surface street concentration of Cesium-137 is 3.00E+09 pCi/m^2 (1.11E+08 Bq/m^2), people limited to 0.5 rem (5 mSv) should be in the contaminated area less thanfour 8-hour days if staying outdoors.

This may apply to individuals retrieving belongings from homes or to workers providing security patrols, or even to people reopening businesses in the area. As contamination levels are reduced during cleanup, stay times can be extended and total doses reduced.</td>
<td>These graphics below are examples based on Operational Guidelines.[c] Please refer to the full report for tables and graphics for use in emergency preparedness.



Limiting Concentrations of Cs-137 for Access to Business

Operational Guidelines for 0.5 rem Annual Dose: Residents Access to Houses (Indoor Exposure)
<table>
<tr><th></th><th colspan="3">Surface Street Concentration (pCi/m^2)</th></tr>
<tr><th>Radionuclide</th><th>1 Day</th><th>4 Days</th><th>12 Days</th></tr>
<tr><td>Am-241</td><td>7.51E+07</td><td>2.86E+07</td><td>1.59E+07</td></tr>
<tr><td>Cf-252</td><td>3.50E+08</td><td>1.32E+08</td><td>7.13E+07</td></tr>
<tr><td>Cm-244</td><td>1.27E+08</td><td>4.82E+07</td><td>2.68E+07</td></tr>
<tr><td>Co-60</td><td>2.72E+09</td><td>6.87E+08</td><td>2.33E+08</td></tr>
<tr><td>Cs-137</td><td>1.14E+10</td><td>2.94E+09</td><td>1.01E+09</td></tr>
<tr><td>Ir-192</td><td>9.93E+09</td><td>2.54E+09</td><td>8.92E+08</td></tr>
<tr><td>Po-210</td><td>1.17E+09</td><td>3.86E+08</td><td>1.74E+08</td></tr>
<tr><td>Pu-238</td><td>6.56E+07</td><td>2.50E+07</td><td>1.39E+07</td></tr>
<tr><td>Pu-239</td><td>6.01E+07</td><td>2.29E+07</td><td>1.27E+07</td></tr>
<tr><td>Ra-226</td><td>6.08E+08</td><td>2.10E+08</td><td>9.97E+07</td></tr>
<tr><td>Sr-90</td><td>2.48E+10</td><td>7.70E+09</td><td>3.18E+09</td></tr>
</table>
</td>
</tr>
</table>

The Safety Requirements document [GS-R-2] requires arrangements to be made for taking effective agricultural countermeasures and for these arrangements to include default Operational Intervention Levels (OILs), including means to revise them.

Clearly, such OILs should be established in advance and be incorporated into the emergency arrangements for facilities in threat categories I and II and for activities within threat category V.

Following the Chernobyl accident, many States implemented controls on contaminated foodstuffs. The activity concentrations used varied considerably as a result of the use of different dose criteria and modelling assumptions, often more as a consequence of political pressure than for scientific reasons. However, this created considerable confusion. As a result, the Codex Alimentarius Commission developed activity concentrations for use in the international trade of foodstuffs.

The activity concentrations in most foodstuffs decrease rapidly with time. Nevertheless, several countries that set up programmes to monitor foodstuffs during that period still continue to monitor routinely imported foodstuffs without necessarily reviewing the need to do so.

The values of the Codex Alimentarius Commission only apply to international trade and do not regulate the internal use of possibly higher levels within the country affected by the accident. However, it is unclear whether this would be understood by the public and they would be willing to accept higher levels in the event of an event within their own country.

Following the Chernobyl accident, the Ministry of Health of the former USSR adopted the following permissible limits of annual dose for the public from the accidental exposure: 100 mSv in 1986, 30 mSv in 1987, and 25 mSv in 1988 and 1989.

As for the emergency workers the permissible limits were as follows: 250 mSv in 1986 (for the military personnel - 500 mSv until 21.05.1986), 100 mSv in 1987, and 50 mSv in 1988 and 1989.

The government of the former USSR initially adopted a criterion for resettlement at a lifetime dose since 1990 of 350 mSv. This value was strongly criticized as being too high and was not applied. In 1991 a lower criterion was adopted in law, which applied a lifetime dose of approximately 70 mSv. This resulted in a much larger number of people leaving at contaminated territory being subject to relocation. The adoption of such a low criteria can, in part, be attributed to the fact that the criteria had not been established before the emergency, and thus were developed during a period of heightened emotions and mistrust following the accident.

During the Goiânia accident, it also was very difficult to set OILs for relocation during the emergency because of time constraints, political pressure and lack of international guidance. The result was the use of excessively cautious assumptions in developing OILs, which in turn resulted in unnecessary protective action, the generation of unnecessary amounts of radioactive waste and unnecessary decontamination and disposal costs. In addition, rather than convincing the public that the action being taken was in their interest, it gave them a feeling that the risk was far greater than actually was the case.

Immediately after the emergency response phase of the Chernobyl, Goiânia and other emergencies had been completed, there was immense pressure from the public, public officials and the media to act and return to normal activities. In the case of the Chernobyl accident, many unjustified efforts were carried out because of this pressure, such as the decontamination of areas that had been evacuated, that would not be resettled in the foreseeable future (e.g. Pripyat).

Many of the attempts to decontaminate villages after the Chernobyl accident were ineffective due to a lack of proper pre-emergency planning. These results produced the general impression that urban decontamination was not worthwhile. Since then, however, it has been demonstrated in the Novozybkov area that simple countermeasures, such as topsoil removal, special digging measures and roof cleaning, can, even 10 to15 years after the Chernobyl accident, significantly reduce the external dose rate[8].

[8] Prister B., Chernobyl catastrophy: efficiency of measures for public protection, experience of international cooperation. Kiev, (2007) 9-12, (In Russian).

During the Goiânia response, additional decontamination was carried out after the official announcement that all decontamination had been completed. This added to public concern and mistrust of officials[9].

Mitigating the non-radiological consequences of the emergency and the response

The non-radiological consequences of the response shall be considered in order to ensure that the response actions do more good than harm.

Jurisdictions within the emergency zones shall make arrangements for justifying, optimizing and authorizing different intervention levels or action levels following an event for which agricultural countermeasures or longer term protective actions are in place. The process shall include arrangements for consulting the people affected. Public concern, effects on economic conditions and employment, long term needs for social welfare and other non-radiological effects of longer term protective actions shall be considered in this process. This process shall provide for exceptions from accordance with international standards where these are justified.

Arrangements shall be made for responding to public concern in an actual or potential nuclear or radiological emergency. Preparations shall include arrangements for promptly explaining any health risks and what are appropriate and inappropriate personal actions for reducing risks. These arrangements shall include monitoring for and responding to any related health effects and preventing inappropriate actions (Inappropriate actions include, for example, discrimination against potentially exposed persons, spontaneous evacuation, the hoarding of food and unwarranted termination of pregnancy) on the part of workers and the public. This shall include the designation of the organization(s) with the responsibility for identifying the reasons for such actions (such as misinformation from the media or rumours) and for making recommendations on countering them. How these recommendations are to be included in the national emergency response shall be specified.

Conclusions

These lessons demonstrate the importance of:

- undertaking mitigatory action following the identification of an event situation as rapidly as possible, as delay can exacerbate the consequences;
- arrangements being in place whereby facility operators and those undertaking activities with dangerous mobile sources (threat category IV) can undertake mitigatory action promptly;
- account being taken in emergency arrangements of the actual conditions — for example, areas of high radiation levels — which may affect the functionality of the emergency arrangements and the performance of the emergency procedures;
- account being taken in emergency arrangements of the information and resource requirements of any off-site agencies providing on-site emergency assistance, and of their need to be contacted rapidly and obtain immediate access to the site;
- developing OILs for various protective actions in advance and incorporating them into the emergency arrangements;
- using internationally harmonized generic OILs and protective actions;
- providing clear explanations to the public in the case of when and why values need to be changed during an emergency;
- numeric levels will not be used to guide restoration and recovery of areas impacted by a radiological incident; rather, planning activities should include a process to involve stakeholders in setting priorities and determining actions. Such a process should be flexible to adapt to a variety of situations.

[9] Lessons learned from the response to radiation emergencies (1945–2010) IAEA, Vienna, 2012.

- planning considerations for worst case scenarios are provided. Smaller radiological incidents may be well addressed by existing emergency response and environmental cleanup programs at local, state, tribal and federal levels.
- reoccupying households and businesses should be considered in balance with progress made in reducing radiation risks through decontamination, radioactive decay, and managing contaminated waste.
- exposure limits that lead to excess lifetime cancer incidence in a range of one in a population of ten thousand (10^{-4}) to one in a population of one million (10^{-6}) are generally considered protective, though this may not be achievable after a large-scale radiological incident. In making decisions about cleanup goals and strategies for a particular event, decision-makers must balance the acceptable level of excess lifetime cancer incidence with the extent of the measures that would be necessary to achieve it.
- incidents that result in large volumes of waste from a large-scale radiological incident would likely overwhelm existing radioactive waste disposal capacity in some countres.
- following a nuclear accident, the States bear primary responsibility to identify and provide waste management options, including disposal capacity.
- safely managing and disposing of radioactive waste will require advance planning at all levels of government and careful coordination with stakeholders at all stages of the decision-making process.
- establishing beforehand methods and criteria for decontamination of areas (streets, roofs, surface soil, subsoil, etc.) to reduce dose rates;
- refraining from declaring decontamination operations as completed until a final assessment confirms that dose reduction goals have been achieved.

TAKING URGENT PROTECTIVE ACTIONS

On-site protective actions and other response actions

A large nuclear accident causes a breakdown in society, affecting all aspects of individual and community life. It has large and long-lasting societal, environmental, and economic consequences. Radiation-related consequences are radiation-induced health effects, such as tissue reactions, cancer, and heritable diseases. In the environment, there are consequences for fauna and flora. In addition to radiation-induced health effects, there may be other health impacts due to changes in lifestyle attributable to protective actions taken to avoid radiation exposure. A large nuclear accident has societal, economic, and psychological consequences. These consequences affect the disturbances to daily life and the well-being of people.

Principles for protection of people and the environment

The objectives of radiological protection are achieved using the fundamental principles of justification of decisions and optimisation of protection. The principle of justification ensures that decisions regarding the implementation of protective actions result in a benefit for the affected people and the environment. The principle of optimisation of protection applied with reference levels aims to limit inequity in the distribution of individual exposures, and to maintain or reduce all exposures to as low as reasonably achievable, taking into account societal, environmental, and economic factors. Justification and optimisation are applied in mitigating radiological consequences during all phases of an accident, and should take careful account of all non-radiological factors in order to preserve or restore the living and working conditions of all those affected, including decent lifestyles and livelihoods.

The application of dose limits is not appropriate in emergency and existing exposure situations following an accident. ICRP defines reference levels to be selected within generic bands of exposure considering the induced risk of radiation as well as the feasibility of controlling the situation.The 2007 Recommendations of ICRP (ICRP, 2007) introduced three types of exposure situation: existing, planned, and emergency. The situation-based approach is a basis of current radiological protection. To manage a large nuclear accident, it is convenient to distinguish between the early and intermediate phases, and the long-term phase. For implementation of the system of radiological protection, ICRP considers the early and intermediate phases as emergency exposure situations, and the long-term phase as an existing exposure situation.

The transition from an emergency exposure situation to an existing exposure situation does not necessarily take place at the same time in all affected areas.Design basis refers to the complete set of requirements and performance standards that define how a component, system, structure, building, or entire plant must be constructed to respond to a given situation. The design basis also generally includes those ongoing tests, reviews, and surveillances that will demonstrate that the as-built configuration continues to meet the design criteria. The design basis is primarily used when making licensing decisions about a plant. Only a plant whose design, construction, and operation meet or exceed the design basis is capable of being licensed to operate. The design basis may include requirements for the design of staffing, procedures, training, engineering evaluations, and other programs to ensure that plant personnel are and remain capable of safely operating the plant.

All aspects of plant operation have a design basis, whether defined by the Commission or by the licensee, including the emergency preparedness and security programs. A plant is permitted to continue to operate after receiving its license as long as it demonstrates that it remains within its design basis.

A design basis accident is a postulated accident that a nuclear power plant must be designed and built to withstand without a loss of the components, systems, or structures necessary to ensure public health and safety. Typically, the design requirement is that, for critical safety functions, a system must be capable of achieving its safety function during the postulated accident even with the failure of any one system component. A design basis accident is used primarily in making licensing decisions, although minimum and maximum operating parameters and equipment testing requirements are derived from the design basis accident.

One aspect of remaining within the plant design basis is operating at all times in a plant configuration capable of respond- ing to a design basis accident. Note that a design basis accident is generally not the worst possible accident or the accident with the greatest consequences. The specific design basis accidents that apply to a plant were selected based on the Commission»s safety goals and probabilistic risk. One way to look at the spectrum of design basis accidents is that they are the most significant accidents that could occur that are expected to be handled entirely by control room operators without requiring significant additional resources (e.g., implementation of the site emergency plan).

For the most part, a design basis accident does cause implementation of the emergency plan as a measure of prudence, rather than because the additional capabilities are needed to ensure adequate protection of the public. This implementation is a prudent step as protection against the very unlikely situation in which the plant configuration degrades to a beyond-design-basis condition.

Emergency preparedness planning basis refers to the collection of facts, policies, and assumptions that define the minimum and maximum scope of an acceptable emergency preparedness program. The basis in effect is a cost–benefit analysis that predefines where planning is done, the scale of that planning, and the performance objectives the planning must achieve (e.g., how severe an accident must the planning handle).

The radiological emergency preparedness planning basis, it broadly consists of the following:

- A spectrum of potential accidents—some result in no core damage, some result in increasing core damage, and some have severe core damage.
- Potential accidents are not limited to licensing design basis accidents; more severe beyond- design-basis accidents are considered in the design of the emergency preparedness program.
- Radiological preplanning is done only in designated emergency planning zones.
- Core damage can occur 15 to 30 minutes after a reactor core is uncovered; radiological source terms can include radioactive gases (gap) or gases mixed with fission products (core melt).
- Releases of radioactive material can initiate 30 minutes to a few hours after core damage occurs.
- Offsite authorities have some warning of core damage and prior to the start of a radiological release, although the warning time may be short.
- The primary options for protective actions for the public are shelter-in-place and evacuation; after 1998, another is issuance of potassium iodide to the public when designated by the state.
- Actions based on the existing emergency plans can be readily expanded beyond the designated emergency planning zone, if necessary.

In addition to defining what the planning basis is, NUREG-0396 discusses the planning basis limits and what the planning basis is not. The expectation is that reasonable, not massive, emer- gency planning programs are established in emergency planning zones. The planning basis specifi- cally excludes requirements for:

- Extensive, large-scale, stockpiles of anti-contamination clothing and provisions for the general public
- Decontamination facilities capable of handling essentially the entire evacuated population and their vehicles and livestock/pets

- New construction of hardened or other specially equipped public shelters; for radiological accident purposes, such facilities could be used in planning where they already exist for other purposes, such as national attack
- Construction of new medical facilities capable of providing treatment of radiological injury on a large (public) scale
- Dedicated permanent emergency stockpiles of non-contaminated food and drink for the general public, or stockpiles of non-contaminated animal feeds for livestock/pets
- Acquisition, staging, storage, or maintenance of sufficient decontamination equipment to provide for the prompt decontamination of land, property, or equipment owned by the public
- Participation by the general public in tests, demonstrations, or evaluations of emergency plan capabilities (e.g., emergency plan exercises).

Following the 2001 terrorist attacks in the United States, the existing emergency preparedness planning basis remained valid and bounded reactor accidents initiated by site attack. By this they primarily meant that, even if adversaries gain effective control over a reactor, severely damage or destroy accessible safety equipment, and disable or prevent the opera- tion of designed safety systems, then the physics of nuclear fission and heat transfer would prevent them from damaging nuclear fuel faster or to a greater degree than the accidents that are already included in (e.g., bounded by) the current emergency planning basis.

Essentially, the planning basis already includes accidents where essential cooling water is removed from the reactor as it operates at full power; taking away cooling water intentionally rather than as the result of a malfunction or pipe break does not worsen the resulting core damage. A terrorist scenario could result in increased radiological risk to the public only if offsite authorities are caught unaware by a major release.

Together, the planning standards address routine and emergency response organization staffing, incident command-and-control, accident assessment measures, the range of onsite and offsite protective responses, response facilities, interfacility communications, public notification and information, emergency responder training, drills and exercises of emergency plans and procedures, and ongoing planning functions.

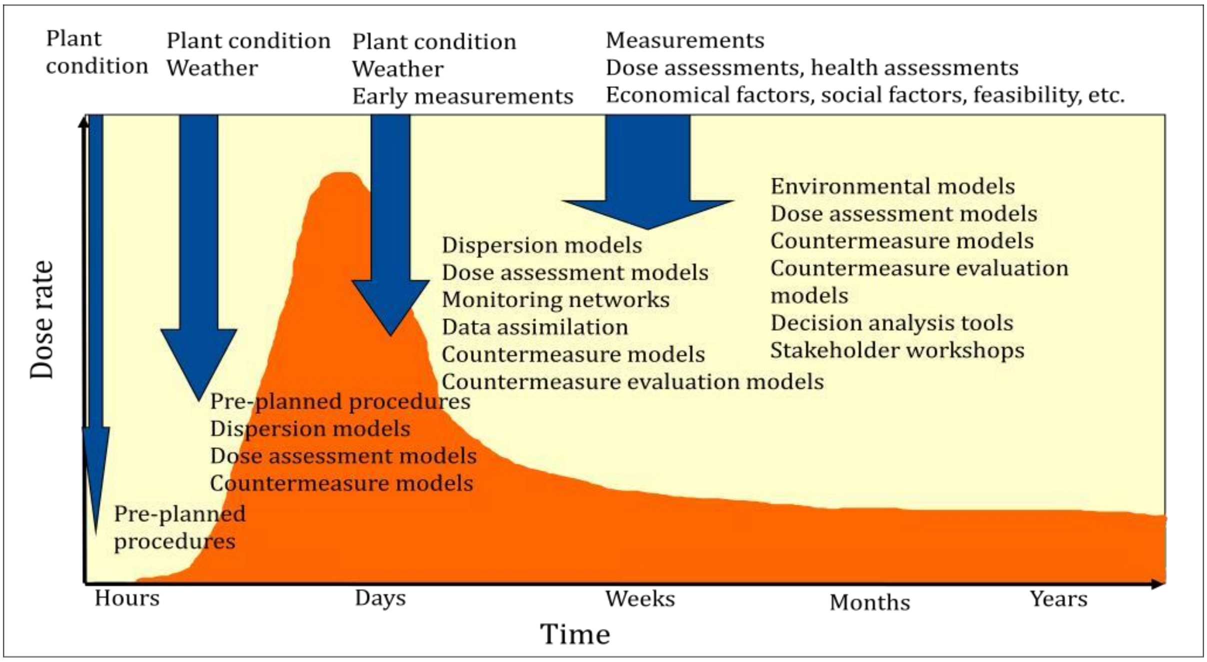


Fig. 6. Temporal variation of dose rate to which the affected people are exposed after a major accident at a nuclear facility, the grounds on which the decisions are based, and actors being involved in decision making

In a nuclear or radiological emergency the affected people are exposed to radiation at variable rates depending on time after the accident. Figure 6 tries to illustrate development of the dose rate after a major accident of a nuclear facility and factors affecting decision making. In early phase of an accident the decision are based normally on technical condition of the accident plant and the prevailing weather condition, and decisions are based on «best estimates». Later on, radiation measurements will be available and decisions on protective actions will more and more be based on them. The figure also indicates the key actors being involved in decision making in different phases of an emergency. In late or recovery phase the number of actors or stakeholders may increase substantially due to the complexity of the situation.

Figure 7 illustrates what kind of decision support tools and methods are needed in different phases of an emergency. In the threat phase, in a very early phase of an emergency, pre-planned procedure are the only available methods to be applied. These procedures shall be part of emergency preparedness plans of the operator and other first responders. In later phases various technical tools, assessment methods and working procedures are needed in decision making. In principle all these tools and methods are available today thanks to extensive research and development performed after the Chernobyl accident in 1986. The only questions are how they can be used in an effective way and if the decision makers are willing to use them.

Special Decision Support Systems (DSS) have been developed for management of radiological emergencies. A DSS is a computer-based information system that supports business or organisational decision making processes. Comprehensive DSSs developed especially for management of nuclear or radiological emergencies are e.g. RODOS and ARGOS used in Europe, RECASS NT used in Russia, ARAC used in US and SPEEDI used in Japan. All these systems are able to make predictions on dispersion of radionuclides in the atmosphere, terrestrial and water environment, dose assessments of people exposed to radiation through different pathways, presentation of radiological data in different forms, etc.

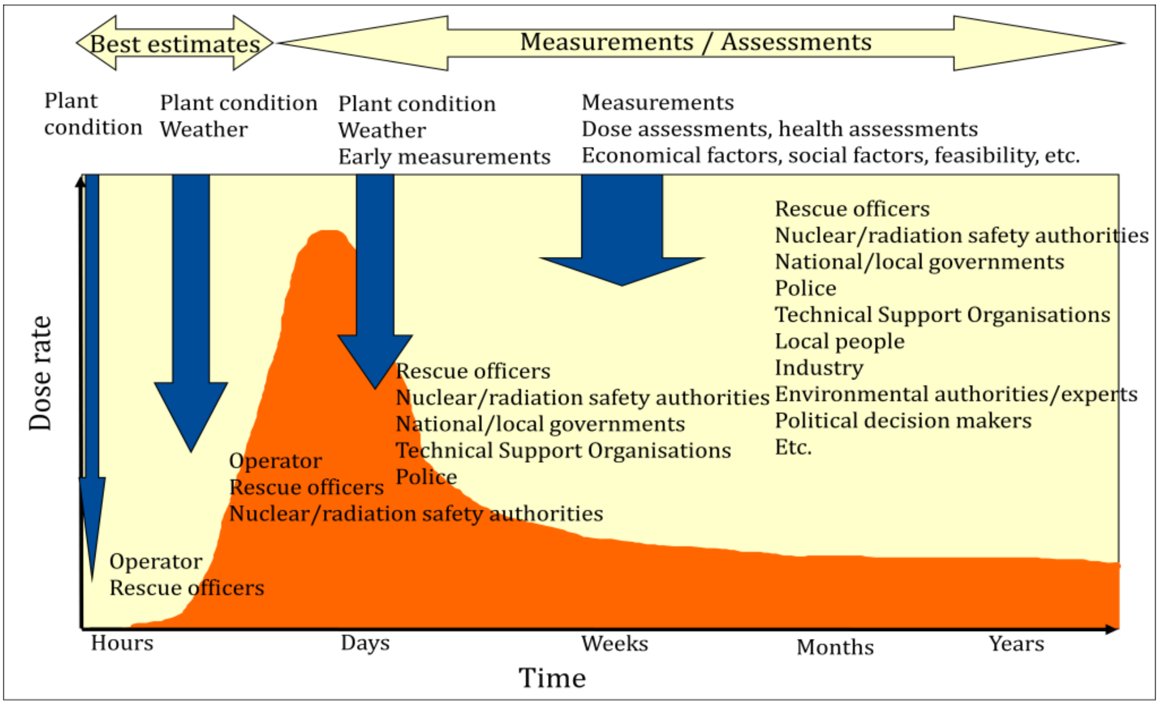


Fig. 7. Decision support tools and methods needed in different phases of a radiological emergency

Of course the exposure situation described in Figures 6 and 7 is not valid in a case of a malicious and intentional dispersion of radioactive material into the environment. Normally in that kind of situation there is no warning time but radioactive material will spread out immediately if an explosives are used, or radioactive material or strong radiation source may already be hided in the environment and the first indicators are e.g. unusual number of symptoms of illness in the area, unexpected amount of sick or dying animals, e.g. birds, insects or fishes, etc. Even small groups of individuals have the ability to cause massive damage and extensive human suffering with little or no warning. Predictably, firefighters, police officers, other emergency management personnel, and civilian volunteers will respond and be on the scene soon after any such event. Because, in addition to radioactive material, also chemical and biological agents may be involved in this kind of attack, all first responders should be well trained and alert to potential risks associated with them. In principle the protective actions and countermeasures are similar to those within an accident situation, but the rescue and other personnel should keep in mind that they are part of a crime scene and they should preserve all evidence when possible.

If conditions are detected in relation to a facility, an activity or a source indicating an actual or potential nuclear or radiological emergency warranting protective actions and other response actions, the emergency class is required to be declared and the preplanned response actions that correspond to the emergency class and the level of emergency response that is warranted are required to be initiated on the site and, as necessary, off the site (see Requirement 7 of GSR Part 7).

Early in the emergency, the response organizations focus their response actions on mitigating the potential consequences of the emergency so that undesirable conditions are prevented from developing, or their development is delayed, making it possible to take effective protective actions on the site and, as necessary, off the site. Such mitigatory actions are accompanied by protective actions and other response actions that are aimed at the potentially or actually affected individuals. Most of these actions are taken as a matter of urgency (i.e. precautionary urgent protective actions, urgent protective actions and other response actions); however, some actions involve more detailed assessments, primarily based on monitoring, and can be taken within days or weeks and still be effective (i.e. early protective actions and other response actions).

Protective actions and other response actions are defined in GSR Part 7, as follows:

“**protective action.** An action for the purposes of avoiding or reducing doses that might otherwise be received in an emergency exposure situation or an existing exposure situation.

early protective action. A protective action in the event of a nuclear or radiological emergency that can be implemented within days to weeks and still be effective.

- The most common early protective actions are relocation and longer term restriction of the consumption of food potentially affected by contamination.

mitigatory action. Immediate action by the operator or other party:

a) To reduce the potential for conditions to develop that would result in exposure or a release of radioactive material requiring emergency response actions on the site or off the site; or

b) To mitigate source conditions that may result in exposure or a release of radioactive material requiring emergency response actions on the site or off the site.

urgent protective action. A protective action in the event of a nuclear or radiological emergency which must be taken promptly (usually within hours to a day) in order to be effective, and the effectiveness of which will be markedly reduced if it is delayed.

- Urgent protective actions include iodine thyroid blocking, evacuation, short term sheltering, actions to reduce inadvertent ingestion, decontamination of individuals and prevention of ingestion of food, milk or drinking water possibly with contamination.

- A precautionary urgent protective action is an urgent protective action taken before or shortly after a release of radioactive material, or an exposure, on the basis of the prevailing conditions to avoid or to minimize severe deterministic effects.”

“***other response action***. An emergency response action other than a protective action.

- The most common other response actions are: medical examination, consultation and treatment; registration and longer term medical follow-up; providing psychological counselling; and public information and other actions for mitigating non-radiological consequences and for public reassurance.”

The safety requirements established in GSR Part 7 and its supporting guidance and recommendations (GS-G-2.1 and GSG-2) address emergency arrangements[10] to be established and implemented in the period after the identification of the conditions leading to the declaration of a nuclear or radiological emergency, until the time the situation is brought under control and radiological conditions are characterized sufficiently well. This period is called the «emergency response phase» and is defined as the period of time from the detection of conditions warranting an emergency response until the completion of all the actions taken in anticipation of or in response to the radiological conditions expected in the first few months of the emergency. The emergency response phase typically ends when the situation is under control, the off-site radiological conditions have been characterized sufficiently well to identify whether and where food restrictions and temporary relocation are required, and all required food restrictions and temporary relocations have been put into effect.

For the purposes of this Safety Guide, the emergency response phase is divided into an urgent response phase and an early response phase (see Fig. 8) as follows:

a) Urgent response phase: The period of time, within the emergency response phase, from the detection of conditions warranting emergency response actions that must be taken promptly in order to be effective until the completion of all such actions. Such emergency response actions include mitigatory actions by the operator and urgent protective actions on the site and off the site. The urgent response phase may last from hours to days depending on the nature and scale of the nuclear or radiological emergency[11].

b) Early response phase: The period of time, within the emergency response phase, from which a radiological situation is already characterized sufficiently well that a need for taking early protective actions and other response actions can be identified, until the completion of all such actions. The early response phase may last from days to weeks depending on the nature and scale of the nuclear or radiological emergency[12].

For the purposes of this Safety Guide, the transition phase is the period of time after the emergency response phase when

a) the situation is under control,

b) detailed characterization of the radiological situation has been carried out and

c) activities are planned and implemented to enable the emergency to be declared terminated.

The transition phase may last from days to months, notwithstanding that for a small scale emergency (e.g. a radiological emergency during transport or a radiological emergency involving a sealed dangerous source) the transition phase may last not more than a day. The termination of the nuclear or radiological emergency marks the end of the transition phase for a particular area or a site and the beginning of either an existing exposure situation or a planned exposure situation (see Fig. 8).

Compared to the urgent response phase and, to some extent, the early response phase, the transition phase is not driven by urgency and allows for adapting, justifying and optimizing protection strategies as the emergency evolves and for interested parties to be consulted. Depending on the nature of the nuclear or radiological emergency, these processes may continue in the longer term after the emergency has been declared terminated. In the transition phase and in the longer term, the implementation of remedial actions might be more efficient than carrying out further disruptive public protective actions.

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[10] These emergency arrangements include arrangements for the implementation of urgent protective actions, early protective actions and other response actions.

[11] For example, the urgent response phase may last just hours in the case of a small scale emergency, such as a radiological emergency during transport or a radiological emergency involving a sealed dangerous source.

[12] For example, the early response phase may last hours to a day in the case of a small scale emergency, such as a radiological emergency during transport or a radiological emergency involving a sealed dangerous source.

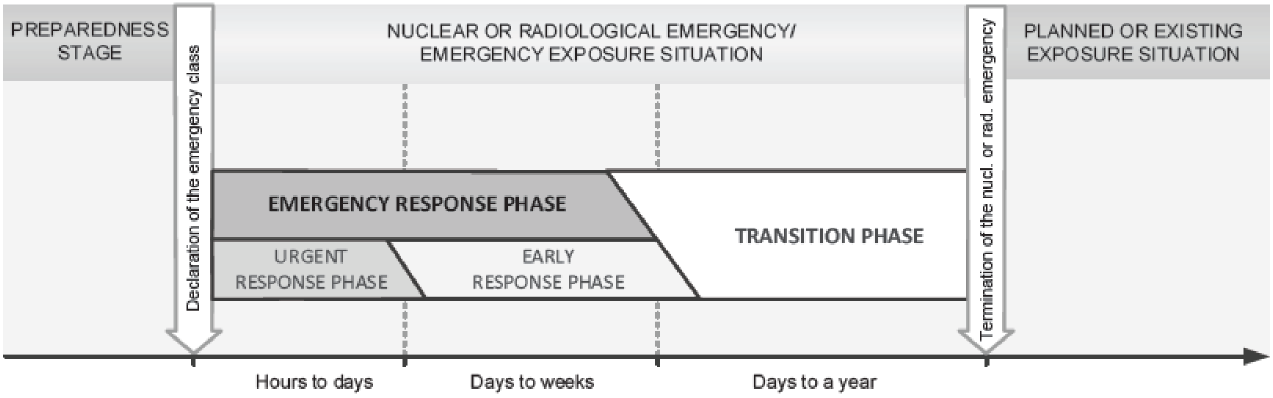

Fig. 8. Temporal sequence of the various phases and exposure situations for a nuclear or radiological emergency within a single geographical area or a single site

Protection strategy at the preparedness stage

GSR Part 7 states that «The government shall ensure that, on the basis of the hazards identified and the potential consequences of a nuclear or radiological emergency, protection strategies are developed, justified and optimized at the preparedness stage for taking protective actions and other response actions effectively in a nuclear or radiological emergency.

The government shall ensure that interested parties are involved and are consulted, as appropriate, in the development of the protection strategy.

The government shall ensure that the protection strategy is implemented safely and effectively in an emergency response through the implementation of emergency arrangements».

The protection strategy should cover, at least, the period from the declaration of the emergency until the termination of the emergency to support the achievement of all the goals of emergency response stated in para. 3.2 of GSR Part 7.

The primary objective and the prerequisites for the termination of the should be the main drivers for the development of the protection strategy for the transition phase.

For a large scale emergency, the implementation of a protection strategy could extend in the longer term within the framework of an existing exposure situation (see WS-G-3.1 and GSG-8). The comprehensive protection strategy developed at the preparedness stage should extend beyond the termination of the emergency to support all the activities necessary for achieving any long term objectives.

The protection strategy for the transition phase developed at the preparedness stage might not be as detailed as the protection strategy for the emergency response phase. This lack of detail is often due to large uncertainties in the prediction of the long term development of the radiological situation for postulated nuclear or radiological emergencies. Other uncertainties are related to social, economic, political and other aspects prevailing at the time of the emergency and the increasing importance of these non-radiological factors later in the response. Thus, the protection strategy for the transition phase should be further elaborated and adapted during the transition phase itself, as relevant information becomes increasingly available. The process for adapting the protection strategy during the emergency response should be agreed, at the preparedness stage, with all relevant authorities and interested parties and should be included in the protection strategy.

As part of the protection strategy, the processes of justification and optimization to cope with the prevailing conditions as the emergency evolves should be agreed on. In general, this agreement should include the following elements:

- The processes and methods to be used in the transition phase, including the designation of any necessary decision aiding tools;
- The parties that will need to be consulted on the inputs necessary for the justification and optimization processes;

- Clearly defined roles and responsibilities for the justification and optimization processes.

As part of the processes of justification and optimization, the protection strategy should take into account the impact that emergency response actions taken during the emergency response phase may have on the actions warranted in the transition phase and in the longer term. The impact that emergency response actions may have on meeting the prerequisites for the termination of the emergency should also be examined and considered. However, such considerations should not compromise the effectiveness of the protection strategy for the emergency response phase.

For example, if two options within the protection strategy provide the same level of protection of the public during the emergency response phase, the one that is less disruptive to society would be the preferred option, as this option will better support later efforts associated with the termination of the emergency and the overall recovery.

Each protection strategy should include:

a) a national reference level, expressed in terms of residual dose from all exposure pathways, to be used as a benchmark for the optimization of protection and safety;

b) generic criteria for taking protective actions and other response actions; and

c) pre-established national operational criteria for initiating the different emergency response actions in line with Requirement 5 of GSR Part 7, with account taken of the recommendations provided in this Safety Guide and in GSG-2.

Public self-help actions aimed at supporting the implementation of the protection strategy should be an integral element of each protection strategy, particularly for the transition phase of a large scale emergency involving a substantial release of radioactive material to the environment.

The development of the protection strategy should involve all response organizations at all levels, as well as relevant interested parties (paras 4.197–4.207 GSG-11) to allow for a common understanding and to enhance the acceptability, feasibility and any associated practicalities of the proposed protection strategy.

When significant radiological consequences could extend beyond national borders, every effort should be made to develop the protection strategy in consultation with neighbouring States that may be directly impacted by the emergency to ensure consistent and coordinated responses.

The protection strategies should be used at the preparedness stage as a framework to guide the establishment of adequate emergency arrangements by all response organizations.

Justification

Responsibility for making decisions on the justification of protection is usually the role of authorities and responsible organisations. The aim is to ensure an overall benefit, in the broadest sense, to society and not necessarily to each individual. There are many aspects of the justification of decisions that can be usefully informed by organisations or individuals outside the authorities. Therefore, ICRP recommends involving key stakeholders in public processes for the justification of decisions whenever possible. ICRP considers that the justification of decisions should be re-assessed regularly as the overall situation resulting from the accident evolves. Therefore, justification is not a «one-off» consideration taken during planning or during the management of an accident. It should question whether the decisions already taken continue to do more good than harm in the broadest sense. The decision to allow people to stay in affected areas should only be taken when the necessary conditions are met, particularly protection against the potential health consequences, and the achievement of suitable living and working conditions, including sustainable lifestyles and livelihoods.

Paragraph 4.29 of GSR Part 7 states that “Each protective action, in the context of the protection strategy, and the protection strategy itself shall be demonstrated to be justified”. The application of the principle of justification allows the respective authorities to determine:

«whether a proposed protective action or remedial action is likely, overall, to be beneficial; i.e. whether the expected benefits to individuals and to society (including the reduction in radiation detriment) from introducing or continuing the protective action or remedial action outweigh the cost of such action and any harm or damage caused by the action» (GSR Part 3).

In determining whether the proposed actions and the protection strategy are justified, the reduction in radiation detriment should be weighed against the impacts in other areas, such as public health, social and economic disruption, ethical considerations and the environment. Examples of such impacts include possible reduced life expectancy owing to stress associated with resettlement, costs associated with the loss of essential infrastructure, loss of productivity of industrial facilities, the need for compensation payments to those impacted, societal impact owing to the loss of places of great cultural or historical importance and the costs to society and its economy associated with the management of the radioactive waste generated.

A justified protection strategy and justified actions within the protection strategy should be developed during the preparedness stage, with account taken of the uncertainties in and limitations of the information available. Protective actions and other response actions implemented solely on the basis of political pressure or public concerns that do not have any scientific and technical merit should be avoided, as these actions may necessitate later remediation activities that are not justified in terms of the associated harm and costs, particularly in the longer term. In addition, taking such unjustified actions may give the impression to the public that the risk associated with the emergency is much greater than the actual risk and therefore may cause unnecessary anxiety and adverse psychological consequences.

The protective actions and the protection strategy should be periodically reassessed in the transition phase to ensure they continue to do more good than harm, with account taken of any new information that becomes available.

Paragraph 4.31(h) of GSR Part 7 requires that protective actions and other response actions be discontinued when they are no longer justified.

Optimization

Implementation of optimisation of protection is a process that requires good understanding of the exposure situation to choose the best protective actions given the particular circumstances. It should reflect the views and concerns of stakeholders, and the ethical values that govern radiological protection. Prudence, justice/equity, and dignity are universal core ethical values that underlie the system of radiological protection, particularly the optimisation principle. The optimisation process inevitably has to cope with conflicts of interest among stakeholders, and must seek to reconcile their different expectations and needs.

One of the characteristics of radiation exposure is the large distribution of exposures received by responders and people living and working in the affected areas. ICRP therefore pays particular attention to equity in the distribution of exposures within groups, and recommends that optimisation of protection should aim to reduce the exposure of the most exposed individuals as a priority.

The optimization of protection and safety should be applied to the protective actions and the protection strategy that justified in accordance with paras 4.39–4.47 GSG-11. The optimization of protection and safety is defined in GSR Part 3 as:

«The process of determining what level of protection and safety would result in the magnitude of individual doses, the number of individuals (workers and members of the public) subject to exposure and the likelihood of exposure being «as low as reasonably achievable, economic and social factors being taken into account»».

The aim is to achieve the best level of protection under the prevailing circumstances; this will not necessarily be the option with the lowest dose.

The process for optimization should allow for all relevant factors (see Table II–1 of Annex II GSG-11) to be considered in the decision making process. Optimization of protection and safety should be a forward looking, iterative process that examines the available options for protection and adjusts the actions to be taken to obtain the best outcome.

Implementation of an optimized protection strategy should result in exposure levels below the reference level, and as low as reasonably achievable, as long as these reductions are justified, with account taken of the aspects indicated in para. 4.44 GSG-11. Optimization should be applied even if the initially projected doses are below the defined reference level, but only if actions that are justified are available to reduce exposures.

Generic criteria and operational criteria

Generic criteria and operational criteria are concepts within the protection strategy that are required to be used to implement protective actions and other response actions in a nuclear or radiological emergency, as described in GSR Part 7 and GSG-2. If the projected dose or the dose that has been received in an emergency exceed the generic criteria, then protective actions and other response actions, either individually or in combination, are required to be implemented.

Paragraph 4.28(3) of GSR Part 7 requires national generic criteria to be developed for the protective actions and other response actions to be taken in an emergency response. Appendix II to GSR Part 7 provides a comprehensive set of generic criteria to be considered when developing a justified and optimized protection strategy at the national level, including when establishing the national generic criteria. The generic criteria given in appendix II to GSR Part 7 are considered to be generically justified and optimized and are intended for application:

a) when taking protective actions and other response actions to avoid or minimize severe deterministic effects, to reasonably reduce the risk of stochastic effects, and to mitigate the economic impact of an emergency by providing a basis for the resumption of international trade, and

b) when guiding actions aimed at enabling the transition to an existing exposure situation.

Appendix II to GSR Part 7 establishes generic criteria for enabling the transition to an existing exposure situation at the following projected doses:

- An effective dose of 20 mSv per year;
- An equivalent dose to a fetus of 20 mSv for the full period of in utero development.

If an emergency occurs, prompt decision making is essential to allow the necessary emergency response actions to be implemented effectively. To facilitate this implementation, operational criteria should be developed on the basis of the generic criteria to trigger specific emergency response actions, without the need for further assessments against the generic criteria and before substantial information on the situation is available. The operational criteria used in the emergency response phase include observable conditions on the site, emergency action levels (EALs) and operational intervention levels (OILs). Further guidance on the criteria to be implemented in emergency preparedness and response can be found in GSG-2.

In the transition phase, OILs based on the generic criteria for taking specific protective actions and other response actions and OILs based on the generic criteria (see para. 4.64 GSG-11) for enabling the transition to an existing exposure situation should be used as a tool to support:

- Decision making on lifting or adapting protective actions, including the determination of what protective actions may need to be lifted or adapted, when the protective actions may need to be lifted or adapted and to whom the decision may apply;
- Implementation of activities to enable the transition from an emergency exposure situation to an existing exposure situation by providing a basis to guide simple activities aimed at reducing the residual dose.

The Appendix GSG-11 provides OILs that should be taken into account when establishing the national OILs to be applied in accordance with para. 4.66 GSG-11. The Appendix also provides considerations as well as a methodology for deriving the OILT to support the implementation of generic criteria to enable the transition to an existing exposure situation.

As for other default OILs, default OILT values should be developed on the basis of conservative assumptions regarding the emergency, the affected population and the prevailing conditions. However, if the characteristics of the emergency differ from those assumed in the calculations of default OILT values, the OILT values should be recalculated using the same methodology but with the new available information. Paragraph 4.28(4) of GSR Part 7 requires that arrangements be established to revise the default OILs in the course of an emergency, with account taken of the prevailing conditions as they evolve. A methodology and processes for the recalculation of the OILT values in the course of an emergency to address the prevailing conditions should be an integral part of the protection strategies.

In revising the default OILs during an emergency, it should be ensured that the situation is well understood and that there are compelling reasons for the revision. The public and other interested parties should be informed of the reasons for any change in the OILs applied in an actual emergency.

The most commonly considered urgent protective actions within a protection strategy are:

a) evacuation;

b) sheltering;

c) iodine thyroid blocking;

d) restrictions on local produce, milk from grazing animals, rainwater or other open sources of drinking water;

e) restrictions on the use of commodities that have the potential to result in significant exposures;

f) decontamination of individuals when appropriate; and

g) actions to prevent inadvertent ingestion.

Many of these urgent protective actions may be implemented as a precaution on the basis of observable conditions or plant conditions before the release of radioactive material or before the occurrence of radiation exposures (precautionary urgent protective actions). A decision on taking urgent protective actions is often based on limited information about the emergency and is guided by conservative assumptions about the potential development and impacts of the exposure situation.

Typical preplanned protective actions that may be implemented at the Site Area Emergency classification include the following:

- Close recreational facilities, parks, and schools in the emergency planning zone and other public facilities with long lead times for implementing evacuation; some offsite jurisdictions close lakes and parks immediately adjacent to reactor sites at an Alert classification due to their close proximity (essentially contiguous) to licensee property.
- Remove food animals from open pasture and place them on stored (covered) food and water.
- Staff access control roadblocks as a precautionary measure (not necessarily implementing access control).
- Staff emergency congregate care shelters and other facilities for receiving the public as a precautionary measure (not necessarily opening the facilities to the public).
- Start shutdown processes for large industrial facilities located in the emergency planning zone, as a precautionary measure to allow the evacuation of plant staff if required.
- Sound public warning sirens and issue public warning messages asking the public to tune to the Emergency Alert System (monitor and prepare).
- When a radiological release is occurring, evacuate the public from an area around the reactor site 2 miles in radius.

Typical preplanned protective actions that are implemented at the General Emergency classification include the following:

- Implement emergency planning zone access control.
- Open congregate care facilities and public decontamination centers.
- Sound public warning sirens and activate the Emergency Alert System to provide emergency information to the public.
- Issue evacuation orders for radiologically affected areas (generally a minimum area 2 miles in radius around the reactor site and 5 miles in the downwind direction).
- Issue shelter-in-place orders for radiologically affected areas in which evacuation is not warranted or in which evacuation cannot be safely accomplished (e.g., competing disasters).
- Embargo home-grown food crops from gardens and fields, embargo home-processed dairy products (especially milk), and prohibit fishing and hunting in the emergency planning zone.
- Recommend the taking of stockpiled potassium iodide (when predistributed to the popula tion) or make stockpiled potassium iodide available (when stocked at a central distribution location).

The philosophy of the regarding evacuations is that

- The immediate or initial preplanned evacuations should be performed based on plant conditions (e.g., a likely or confirmed severe core damage sequence) without requiring definitive evidence of, or confirmation of, a radiological release.
- The minimum possible area consistent with federal radiological guidelines should be evacuated.
- Evacuation orders should be expanded to as far away as necessary based on projected dose without requiring evidence of, or confirmation of, a radiological release, or based on a confirmed radiological release that has not yet reached the at-risk populations.
- All members of the public in and near the emergency planning zone not affected by an evacuation order should stay indoors and near an information source and should prepare to evacuate if necessary.

Protective actions are typically recommended in at least a three-sector section because the true wind direction throughout the affected area is not known, the true plume location is not known prior to environmental monitoring, and because plumes do not travel in straight lines because of terrain effects. A sector is a wedge-shaped geographical area whose outer edge covers 1/16 of the perimeter of a circle (22.5° of arc), so a three-sector-wide section covers 3/16 of the 5-mile radius perimeter.

The wind direction is not truly known because the onsite meteorological tower only provides an approximation of offsite conditions that is valid for 1 to 2 miles downwind. In addition, there may be significant uncertainties about wind persistence times (e.g., stability in the wind direc- tion). Licensees with the capability to obtain wind data from multiple meteorological towers in the emergency planning zone may be capable of making more precise recommendations (e.g., two sectors or a single sector).

Close to the reactor site, an individual sector is very thin, and as downwind distances increase the off-center sectors provide a margin of time to implement protective actions when wind directions change. Some licensees have implemented a protective action scheme that includes a four-sector-wide downwind area when the downwind wind direction is along a sector boundary line. In this regard that, “it may be appropriate to include more than three downwind sectors in an expanded evacuation,” based on site-specific wind persistence studies.

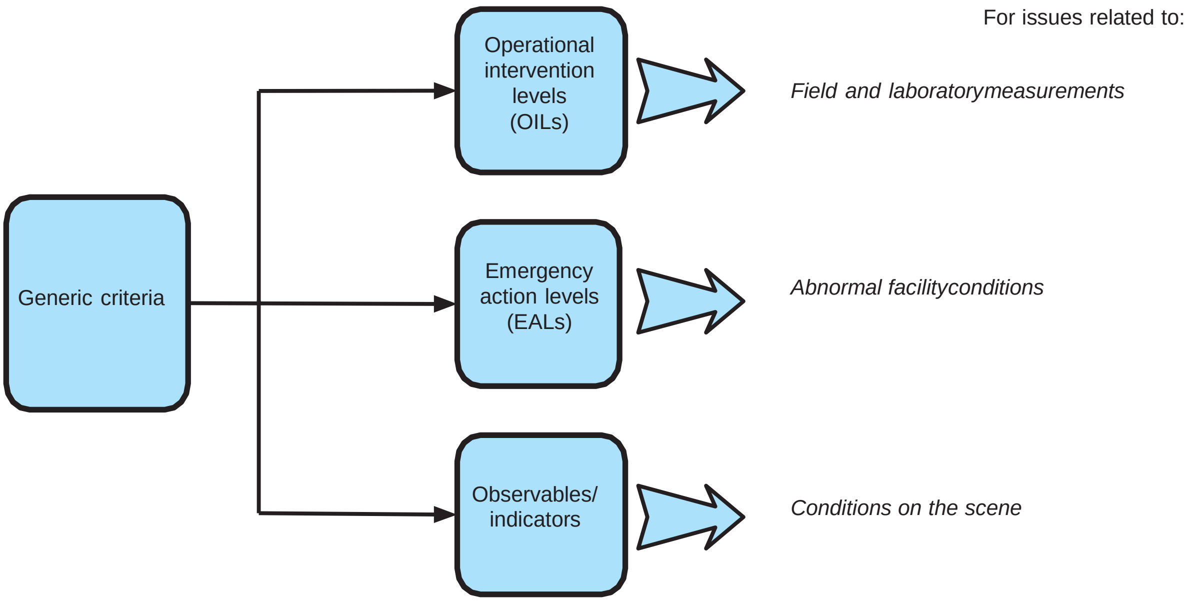

Fig. 9. System of generic criteria and operational criteria

Also, "modifications may be appropriate for areas where the typical site meteorology includes wind direction shifts on a timescale that is shorter than the ETE [evacuation time estimate] for downwind 2- to 5-mile sectors."

The following considerations form the basis of the emergency arrangments:

– The following possible outcomes should be considered during the planning and implementation of protective actions and other response actions in an emergency:

• Development of severe deterministic effects;
• Increase in stochastic effects;
• Adverse effects on the environment and property;
• Other adverse effects (e.g. psychological effects, social disorder, economic disruption).

– The following types of exposure should be taken into account in the planning and implementation of protective actions and other response actions in an emergency:

• The projected dose that could be prevented or reduced by means of precautionary urgent protective actions;

• The dose that has been received, the detriment due to which may be minimized by, for example, medical actions, as required, and may be addressed by public reassurance or counselling.

– Precautionary urgent protective actions should be implemented before the event (on the basis of a substantial risk of a release or exposure) under any circumstances, in order to prevent the development of severe deterministic effects for very high levels of dose (generic criteria are presented in Table 9).

– If the risk of stochastic effects is the main concern and the risk of the development of severe deterministic effects is negligible, urgent and early protective actions and other response actions, all of which are justified and optimized, should be implemented to reduce the risk of stochastic effects (generic criteria are presented in Table 10).

– If the dose exceeds a particular generic criterion identified in Table 9 or 10, individuals should be provided with appropriate medical attention, including medical treatment, long term health monitoring and psychological counselling.

– For all levels of dose that may result in an emergency exposure situation, a plain language explanation of the risks should be provided to decision makers and the public to allow them to make informed decisions about what actions they will take.

Table 9

Generic criteria for acute doses for which protective actions and other response actions are expected to be taken under any circumstances to avoid or to minimize severe deterministic effects

Generic criteria		Examples of protective actions and other response actions
External acute exposure (<10 hours)		If the dose is projected: – Take precautionary urgent protective actions immediately (even under difficult conditions) to keep doses below the generic criteria – Provide public information and warnings – Carry out urgent decontamination
$AD_{Redmarrow}$[a]	1 Gy	
AD_{Fetus}	0.1 Gy	
AD_{Tissue}[b]	25 Gy at 0.5 cm	
AD_{Skin}[c]	10 Gy to 100 cm2	
Internal exposure from acute intake (Δ = 30 days)[d]		If the dose has been received: – Perform immediate medical examination, consultation and indicated medical treatment – Carry out contamination control – Carry out immediate decorporation[f] (if applicable) – Carry out registration for long term health monitoring (medical follow-up) – Provide comprehensive psychological – counselling
$AD(\Delta)_{Redmarrow}$	0.2 Gy for radionuclides with Z ≥ 90[e] 2 Gy for radionuclides with Z ≤ 89[e]	
$AD(\Delta)_{Thyroid}$	2 Gy	
$AD(\Delta)_{Lung}$[g]	30 Gy	
$AD(\Delta)_{Colon}$	20 Gy	
$AD(\Delta')_{Fetus}$ [h]	0.1 Gy	

[a] $AD_{Red\ marrow}$ represents the average RBE weighted absorbed dose to internal tissues or organs (e.g. red marrow, lung, small intestine, gonads, thyroid) and to the lens of the eye from exposure in a uniform field of strongly penetrating radiation.
[b] Dose delivered to 100 cm^2 at a depth of 0.5 cm under the body surface in tissue due to close contact with a radioactive source (e.g. source carried in the hand or pocket).
[c] The dose is to the 100 cm^2 dermis (skin structures at a depth of 40 mg/cm^2 (or 0.4 mm) below the body surface).
[d] AD(Δ) is the RBE weighted absorbed dose delivered over the period of time Δ by the intake (I_{05}) that will result in a severe deterministic effect in 5% of exposed individuals.
[e] Different criteria are used to take account of the significant difference in the radionuclide specific intake threshold values for the radionuclides in these groups.
[f] The generic criterion for decorporation is based on the projected dose without decorporation. Decorporation is the biological processes, facilitated by a chemical or biological agent, by which incorporated radionuclides are removed from the human body.
[g] For the purposes of these generic criteria, 'lung' means the alveolar-interstitial region of the respiratory tract.
[h] For this particular case, Δ′ means the period of in utero development.

Table 9 summarizes, for different types of possible health consequences of exposure, the basis for implementation of protective actions and other response actions.

The system of generic criteria and operational criteria is illustrated in Fig. 9. Generic criteria are provided in terms of dose that can be projected or dose that has already been received. The operational criteria are values of measurable quantities or observables that include operational intervention levels (OILs), emergency action levels (EALs), specific observables and other indicators of conditions on the scene that should be used in decision making during an emergency. The operational criteria can be used immediately and directly to determine the need for appropriate protective actions and other response actions.

Table 10

Generic criteria for protective actions and other response actions in emergency exposure situations to reduce the risk of stochastic effects

Generic criteria		Examples of protective actions and other response actions
Projected dose that exceeds the following generic criteria: Take urgent protective actions and other response actions		
$H_{Thyroid}$	50 mSv in the first 7 days	Iodine thyroid blocking
E H_{Fetus}	100 mSv in the first 7 days 100 mSv in the first 7 days	Sheltering; evacuation; decontamination; restriction of consumption of food, milk and water; contamination control; public reassurance
Projected dose that exceeds the following generic criteria: Take protective actions and other response actions early in the response		
E H_{Fetus}	100 mSv per annum 100 mSv for the full period of in utero development	Temporary relocation; decontamination; replacement of food, milk and water; public reassurance
Dose that has been received and that exceeds the following generic criteria: Take longer term medical actions to detect and to effectively treat radiation induced health effects		
E	100 mSv in a month	Screening based on equivalent doses to specific radiosensitive organs (as a basis for medical follow-up); counselling
H_{Fetus}	100 mSv for the full period of in utero development	Counselling to allow informed decisions to be made in individual circumstances

Note: H_T — equivalent dose in an organ or tissue T; E — effective dose.

Generic criteria have been established on the basis of generic optimization in consideration of the range of conditions that prevail in an emergency. Generic criteria are established for urgent protective actions and early protective actions, as well as for other response actions that may be required in an emergency.

Urgent protective actions (e.g. evacuation) should be taken promptly (e.g. within hours) to be effective, because their effectiveness will be reduced by delay.

Less disruptive protective actions such as sheltering could be implemented for lower doses.

In the absence of national guidance, the generic criteria presented in Tables 9 and 10 could be used as a basis for the development of criteria at the national level. If a reference level different from 20–100 mSv is chosen, appropriate scaling of the values of the generic criteria in Table 10 should be carried out, with account taken of the time frame (acute or annual) of the reference level. In exceptional circumstances, higher values of the generic criteria may be necessary.

Examples of when such higher values of generic criteria in exceptional circumstances may be warranted include cases in which replacement food or water is not available, cases of extreme weather conditions, natural disasters, the rapid progression of a situation and cases of malicious acts. Generic criteria used in such cases should not exceed those presented in Table 10 by a factor of more than 2–3.

A protection strategy, comprising specific protective actions and other response actions, should be developed. It should include, but should not be limited to, the following aspects:

- Generic criteria for implementing precautionary urgent protective actions to prevent severe deterministic effects should be established (see Table 9).

− A reference level should be set, typically an effective dose of between 20 and 100 mSv, expressed in terms of residual dose, which includes dose contributions via all exposure pathways. The protection strategy should be optimized to reduce exposures below the reference level.

− On the basis of the outcome of the optimization of the protection strategy, and by using the reference level, generic criteria for particular protective actions and other response actions, expressed in terms of projected dose or dose that has been received, should be developed. If the numerical values of the generic criteria are expected to be exceeded, those actions, either individually or in combination, should be implemented. Table 10 provides a set of generic criteria for use in the protection strategy that are compatible with reference levels within a range of 20–100 mSv, as well as further details for specific actions in different time frames. The implementation of protective actions and other response actions, given in Table 10, would prevent a significant amount of dose.

− Once the protection strategy has been optimized and a set of generic criteria has been developed, default triggers for initiating the different parts of an emergency response plan, primarily for the early phase, should be derived from the generic criteria. Default triggers, such as conditions on the scene, OILs and EALs, should be expressed in terms of parameters or observable conditions. Arrangements should be established in advance to revise these triggers, as appropriate, in an emergency exposure situation, with account taken of the prevailing conditions as they evolve.

Table 9 presents generic criteria (expressed in terms of the dose that is projected or dose that has been received) for taking precautionary urgent protective actions under any circumstances to prevent severe deterministic effects.

Table 10 provides a set of generic criteria expressed in terms of the dose that has been projected or the dose that has been received. The set of generic criteria expressed in terms of the projected dose is compatible with reference levels within a range of 20–100 mSv. Taking protective actions at this level of dose will allow the occurrence of all deterministic effects to be avoided and the risk of stochastic effects to be reduced to acceptable levels. If a protective action is implemented effectively, the majority of the projected dose can be averted. The concept of averted dose is therefore useful for the assessment of the efficiency of individual protective actions or their combination.

The concept of averted dose represents an important component of the optimization of emergency response planning. In the application of generic criteria for individual protective actions, the process of optimization of emergency response planning should be applied.

The generic criterion provided in Table 10 for iodine thyroid blocking is applied for an urgent protective action:

a) if exposure due to radioactive iodine is involved,

b) before or shortly after a release of radioactive iodine, and

c) within only a short period after the intake of radioactive iodine.

Operational criteria

Projected dose and dose that has been received are not measurable quantities and cannot be used as a basis for quick actions in an emergency. There is a need to establish – in advance – operational criteria (values of measurable default quantities or observables) as a surrogate for the generic criteria for undertaking different protective actions and other response actions. Precautionary urgent protective actions and, as applicable, urgent protective actions should be taken on the basis of precalculated default operational criteria. The majority of urgent protective actions and early protective actions are also implemented on the basis of precalculated default operational criteria. However, if the characteristics of an emergency differ from those assumed in the calculations of default operational criteria, the criteria should be recalculated. Methods for the recalculation to address prevailing conditions in an actual emergency should be established during the planning phase.

The operational criteria[13] are the EALs, OILs, observables and indicators of conditions on the scene.

The EALs are the specific, predetermined, observable operational criteria used to detect, recognize and determine the emergency class of an event at facilities in threat categories I, II and III. The EALs are used for classification and for decisions on the implementation of precautionary urgent protective actions corresponding to the emergency class. These criteria should be predefined and implemented. Appendix III GSG-2 provides a discussion of the EAL development process and gives examples of EALs for the classification of emergencies at a light water reactor nuclear power plant.

For emergencies in threat category IV, the operational criteria for implementing urgent protective actions should be predetermined on the basis of information that will be observable on the scene. Usually observations that indicate a radiation hazard will be made by first responders or operators on the scene (e.g. upon seeing a placard on a vehicle that has been involved in an accident).

Standarts provide guidance on the approximate radius of the inner cordoned area in which urgent protective actions would initially be taken on the basis of information observable by responders upon their arrival on the scene. The size of the cordoned area may be expanded on the basis of dose rate OILs and other environmental measurement OILs (see Appendix II GSG-2) when these data become available.

Manual[14] provides a list of observables that can be used by responders to identify a dangerous source, together with the actions to be taken to protect responders and the public.

Reference[15] provides guidance on the activity of a radionuclide that, if not controlled, should be considered to constitute a dangerous source.

The OIL is a calculated quantity that corresponds to one of the generic criteria. The OILs are used with the other operational criteria (EALs and observables) to determine appropriate protective actions and other response actions. If the OILs are exceeded, the appropriate protective action should be promptly invoked. The OILs are typically expressed in terms of dose rates or activity of radioactive material released, time integrated air concentrations, ground or surface concentrations, or activity concentration of radionuclides in the environment, in food, in water or in biological samples. OILs can be measured by means of instruments in the field or can be determined by means of laboratory analysis or assessment.

"Arrangements shall be made for promptly assessing the results of environmental monitoring and monitoring for contamination on people in order to decide on or to adapt urgent protective actions to protect workers and the public, including the application of operational intervention levels (OILs) with arrangements to revise the OILs as appropriate to take into account the conditions prevailing during the emergency."

Default OILs shall be established together with the means to revise the OILs for "environmental measurements (such as dose rates due to deposition and deposition densities) and food concentrations; the means to revise the OILs; timely monitoring...for ground contamination in the field; the sampling and analysis of food and water; and the means to enforce agricultural countermeasures."

Every effort should be made to keep the system simple by keeping the number of OILs to a minimum. In principle, the default OILs should be a minimum set for each operational quantity (e.g. dose rate due to skin contamination) that, with due consideration of the uncertainties, reasonably encompasses the protective action (e.g. urgent decontamination), applicable generic criteria and associated assumptions (e.g. the type of emergency or the characteristics of the radiological hazard).

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[13] These operational criteria are used as triggers at the early stage of an emergency; in some publications the term 'trigger' is used.

[14] Manual for First Responders to a Radiological Emergency, EPR-FIRST RESPONDERS (2006), IAEA, Vienna (2006).

[15] Dangerous Quantities of Radioactive Material, EPR-D-VALUES (2006), IAEA, Vienna (2006).

It is possible that, during an emergency, individuals might receive doses that give rise to a high risk of incurring radiation induced cancers. Although it is unlikely, there might be a detectable increase in the incidence of cancers among the population group that has been exposed, owing to radiation induced cases of cancer. Emergencies have occurred for which no criteria for long term health monitoring and treatment had been pre-established. Criteria that have been established after emergencies have occurred have often been set at too low a level of dose received or have not been set on the basis of radiation dose criteria at all. This has led to the designation of groups for follow-up for which it would have been impossible, because of the inherent limitations of epidemiological studies, to detect any increase in the incidence of cancers, owing to the relatively small number of cases of radiation induced cancer to be expected. Default operational criteria are therefore needed for determining whether a person should be considered for long term health monitoring and treatment.

Standarts states a requirement for guidelines relating to the diagnosis and treatment of radiation injuries. These guidelines should include operational criteria used in the dosimetric support of medical management of the patient.

The dosimetric models for developing the OILs should be established during the planning phase. These models should include a full set of parameters important for the purposes of decision making for dose assessment. For internal dose assessment and the development of corresponding OILs, the application of computer codes is necessary.

The dosimetric models and data should provide reliable assurance that all members of the public, including those that are most sensitive to radiation (e.g. pregnant women), are considered. In the development of the default operational criteria, the public needs to be assured that all groups (e.g. children playing outdoors) have been considered. Consequently, the OILs must be accompanied by a plain language explanation of the situation to which they apply (see Appendix II), the way in which they address a safety or health concern, and what their application means in terms of the risk to individuals.

These default OILs should be developed on the basis of assumptions regarding the emergency, the affected population and the prevailing conditions; these assumptions, however, may not accurately reflect the emergency in question. Consequently, standarts requires that means be established to revise the default OILs to take into account prevailing emergency conditions. However, revising the OILs during an emergency may be disruptive, and they should therefore only be revised if the situation is well understood and there are compelling reasons to do so. The public should be informed of the reasons for any change in the OILs applied in an actual emergency.

Appendix II GSG-2 provides selected examples of default OILs for deposition, levels of individual contamination, and contamination levels for food, milk and water, together with a plain language explanation of the OILs.

Considerations for the adaptation or lifting of specific protective actions

Iodine thyroid blocking

Iodine thyroid blocking is a short term urgent protective action that provides protection for the thyroid against radioactive iodine. Iodine thyroid blocking may be implemented as a precaution, although it is not usually a stand-alone action but rather is combined with other protective actions such as sheltering. Iodine thyroid blocking is not a protective action to be implemented for prolonged periods, although under some circumstances repeated administration of stable iodine might be considered. Whenever there is a need to implement iodine thyroid blocking for a longer duration (e.g. for several days), consideration should be given to implementing evacuation or relocation. Iodine thyroid blocking is suitable for use in the urgent response phase and is not appropriate for implementation in the transition phase. Iodine thyroid blocking is adapted or lifted in the emergency response phase.

Sheltering

Sheltering is also an urgent protective action that is relatively easy to implement in an emergency, either as a precaution or as an urgent protective action to be taken for a short time until more effective but more disruptive actions (e.g. evacuation) can be safely implemented. Sheltering should not be carried out for long periods (more than approximately two days). Sheltering is not appropriate for implementation in the transition phase but may be lifted or adapted during this phase.

Aspects to be considered in the decision to adapt or lift sheltering imposed during the emergency response phase should include:

The level of protection offered by the types of buildings used for sheltering (shielding factor and tightness against diffusion of outside atmosphere);

The need for continued simultaneous implementation of iodine thyroid blocking when appropriate;

The medical care and other needs of those sheltered (e.g. the availability of medicines, food supplies, clean clothing and sanitation);

Any necessity to gradually increase the time recommended for members of the public to spend outdoors until sheltering is fully lifted, with account taken of the need for any instructions to be given on areas to be avoided while outdoors;

The need for further protective actions based on generic criteria and OILs to replace sheltering (e.g. evacuation or relocation).

Evacuation

Evacuation may be taken as a precautionary action on the basis of observable conditions or plant conditions (i.e. EALs) or as an urgent protective action based on OILs. Because of the temporary nature of evacuation, priority should be given to lifting this protective action, with consideration given to the following (see the Appendix):

In an evacuated area where the monitoring results indicate that the projected doses may exceed the generic criteria for relocation (i.e. the measurement results exceed OIL2 of GSG-2), evacuation should be substituted by relocation to provide better living conditions for evacuees.

In an evacuated area where the monitoring results indicate that the projected doses do not exceed the generic criteria for relocation (i.e. the measurement results do not exceed OIL2 of GSG-2), evacuation should be lifted if no or only limited restrictions (e.g. restrictions on locally produced food or limited access to certain recreational areas) would continue to be necessary for those people living normally in the area and if the preconditions in para. 4.101 GSG-11 are fulfilled.

In an evacuated area where the monitoring results indicate that the projected doses do not exceed the generic criteria for relocation (i.e. the measurement results do not exceed OIL2 of GSG-2), but limited restrictions are not sufficient for the protection of the people returning to live normally in the area, or the preconditions in para. 4.101 GSG-11 are not fulfilled, evacuation should not be lifted until this area can be managed as an existing exposure situation, after fulfilment of the preconditions in para. 4.101 GSG-11.

If the responsible authorities cannot fulfil some of the relevant prerequisites in para. 4.101 GSG-11 for evacuated areas, such areas should be delineated, and relocation can be considered instead of evacuation for these areas to enable the timely termination of the emergency.

In areas with circumstances such as those referred to in para. 4.81(c), OILT (as provided in the Appendix GSG-11) should be applied to guide remedial actions for preparing these areas so that people may live normally with limited restrictions. In deciding whether to allow people to return to these areas, the residual doses from all exposure pathways — based on the actual circumstances — should be considered, with account taken of the limited restrictions continuing to be in place.

When substituting evacuation with relocation, the people evacuated should be granted access to the evacuated areas for short periods of time and in a controlled manner to allow them to prepare for longer term relocation.

Relocation

Relocation is an early protective action intended for longer duration (months). The adaptation or lifting of relocation is less urgent than for evacuation; therefore, more time is available for planning. Relocation should be lifted under the same conditions as those applicable for lifting evacuation outlined in paras 4.81(b) and (c) and 4.82 GSG-11.

Restrictions on food, milk and drinking water

Restrictions that were imposed on food, milk and drinking water as a precaution in the emergency response phase on the basis of estimates (e.g. on the basis of EALs or OIL3 of GSG-2 and thereafter adjusted on the basis of OIL5 and OIL6 of GSG-2 or OIL7) should be characterized in detail in the transition phase. The purpose is to identify food production areas and foodstuffs that need to remain under restriction even in the longer term and to identify those restrictions that need to be lifted. OILs for restrictions of food, milk and drinking water derived on the basis of sampling and analysis (i.e. OIL6 in GSG-2) should be used when considering whether to adapt or lift this protective action.

OIL6 in GSG-2 has been derived on the basis of the generic criterion of a projected effective dose of 10 mSv per year and uses extremely conservative assumptions (see GSG-2 for more details). In the transition phase, the actual doses received from the ingestion pathway and their contribution to the residual dose should be estimated on the basis of actual conditions to aid in decision making on the adaptation or lifting of this protective action. Under actual conditions, the contribution of actual doses from the ingestion pathway to the total residual dose is expected to be significantly less than 10 mSv effective dose per year.

For existing exposure situations, Requirement 51 of GSR Part 3 requires that specific reference levels be established for exposure due to radionuclides in commodities including food and drinking water, each of which is typically required to be expressed as, or based on, an annual effective dose to the representative person that does not generally exceed a value of about 1 mSv. In addition, the World Health Organization has issued guidelines for drinking water quality that provide guidance levels for radionuclides in drinking water for prolonged situations of exposure resulting from past emergencies. Thus, further restrictions on food, milk and drinking water extending into the longer term in an existing exposure situation might be implemented in order to eventually achieve these levels.

The implementation, adaptation or lifting of restrictions on the international trade of food, milk and drinking water should take into account established national criteria (GSR Part 7 and GSR Part 3).

To reassure the public of the radiation safety of food, milk and drinking water in the transition phase, the relevant authorities should provide evidence for compliance with applicable national regulations. Such evidence should include publishing of monitoring results, including information that places the radiological health hazards in perspective and, where appropriate, certification.

Restriction on non-food commodities

Decisions on the adaptation or lifting of restrictions on non-food commodities implemented during the emergency response phase as a precaution or based on estimates (e.g. on the basis of EALs or OIL3 of GSG-2) should be based on comprehensive information and actual monitoring results. The purpose is to identify non-food commodities that are justified to remain under restriction even in the longer term and to identify those restrictions that need to be lifted. OILs for non-food commodities derived on the basis of sampling and analysis (referred to in this publication as OILC) should be used for this purpose. A methodology to derive default OILC values is given in the Appendix GSG 11.

In the transition phase, the actual doses received from the use of non-food commodities and the contribution of these doses to the residual dose should be estimated on the basis of the actual circumstances. These estimates should be used to inform decision making on the adaptation or lifting of restrictions on the use of non-food commodities.

Requirement 51 of GSR Part 3 establishes the specific reference level for commodities in the longer term in an existing exposure situation as an annual effective dose of about 1 mSv. Further restrictions on non-food commodities extending to the longer term in an existing exposure situation might be implemented to achieve this reference level.

The implementation, adaptation or lifting of restrictions on the international trade of non-food commodities should be determined on the basis of OILs derived from the respective generic criteria given in appendix II to GSR Part 7. The methodology given in the Appendix GSG-11 can also be used to derive OILC values.

To reassure the public of the radiation safety of non-food commodities in the transition phase, the relevant authorities should provide evidence for compliance with applicable national regulations. Such evidence should include publishing of monitoring results, including information that places the radiological health hazards in perspective, and, where appropriate, certification.

Emergency planning zones and distances, safety perimeter

The GS-R-2 establish numerous requirements relating to generic areas:
- on the site (on-site) and
- off the site (off-site).

In addition, the GS-R-2 establish requirements for two off-site emergency zones:
- the precautionary action zone (PAZ) and
- the urgent protective action planning zone (UPZ).

Finally, the GS-R-2 establish requirements for areas in threat category V.

On-site area

The on-site area is the area under the control of the operator or first responders.

For facilities in threat category I, II or III, the on-site area is the area surrounding the facility within the security perimeter, fence or other designated property marker that is under the immediate control of the facility operator.

Types of event associated with radiological emergencies:
- Detection of medical symptoms of radiation exposure due to unknown sources
- Lost dangerous source
- Theft of a dangerous source
- Found dangerous source
- Recovery of an uncontrolled dangerous source
- Radiography: disconnected or damaged source
- Radiography: source in a fire
- Damage to a fixed dangerous sealed source (e.g. as used in gauges)
- Public contamination and/or exposure (including that caused intentionally)
- Re-entry of a satellite containing radioactive material
- Accident with a nuclear weapon
- Transport emergency
- Emergency in radiology or nuclear medicine
- Emergency in radiotherapy

- A serious overexposure
- Credible or confirmed terrorist threats
- Non-credible terrorist threats
- An explosive radiological dispersal device
- Intentional contamination of water supply
- Intentional contamination of food and/or other products
- Detection of elevated radiation levels (in air, water, food or other products)
- Notification of a transnational emergency by the IAEA or any State

For licensed practices using radiography sources or other dangerous sources in threat category IV this is the area under the control of the operator.

For radiological emergencies involving transport, uncontrolled sources or localized contamination the first responders should establish a security perimeter containing the inner and outer cordoned areas to define the on-site area. This is shown below (Fig. 10. Appendix II GS-R-2 provides suggested sizes for the inner cordoned area for various radiological emergencies).

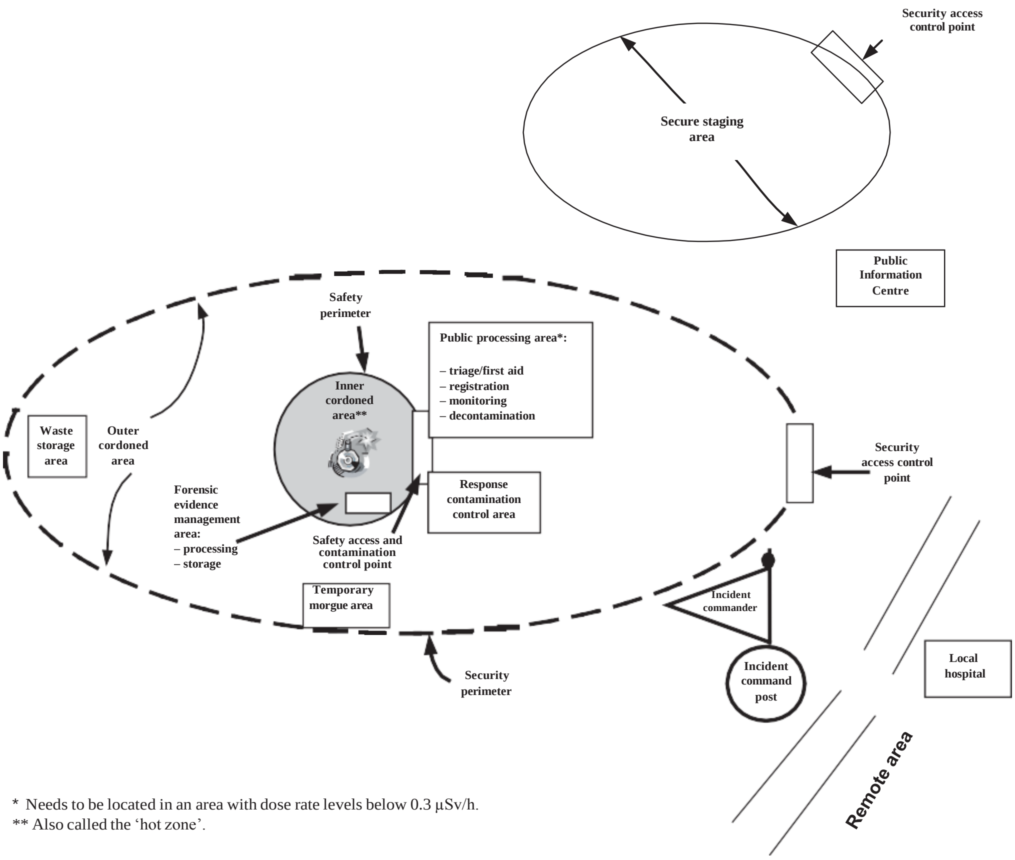

Fig. 10. Areas established by first responders (Appendix VIII GS-R-2 provides a description of some of the facilities and locations shown)

Off-site area

The off-site area is the area beyond that area under the control of the facility, operator or first responders.

The GS-R-2 require that, for facilities in threat category I or II, arrangements be made for effectively making and implementing decisions on urgent protective actions to be taken off the site within:

- A precautionary action zone, for facilities in threat category I, for which arrangements shall be made with the goal of taking precautionary urgent protective action, before a release of radioactive material occurs or shortly after a release of radioactive material begins, on the basis of conditions at the facility (such as the emergency classification) in order to reduce substantially the risk of severe deterministic health effects.

- «An urgent protective action planning zone, for facilities in threat category I or II, for which arrangements shall be made for urgent protective action to be taken promptly, in order to avert dose off the site in accordance with international standards.»

The PAZ and UPZ should be roughly circular areas around the facility, and their boundaries should be defined, where appropriate, by local landmarks (e.g. roads or rivers) to allow easy identification during a response, as illustrated in Fig. 11. It should be noted that the zones should not stop at national borders. The size of the PAZ and the UPZ should be in accordance with the guidance provided in Appendix II GS-R-2.

The Requirements establish requirements for areas with activities in threat category V. Threat category V includes activities that might yield products with a significant likelihood of becoming contaminated, as a result of events at facilities in threat category I or II, to levels necessitating prompt restrictions on products in accordance with international standards.

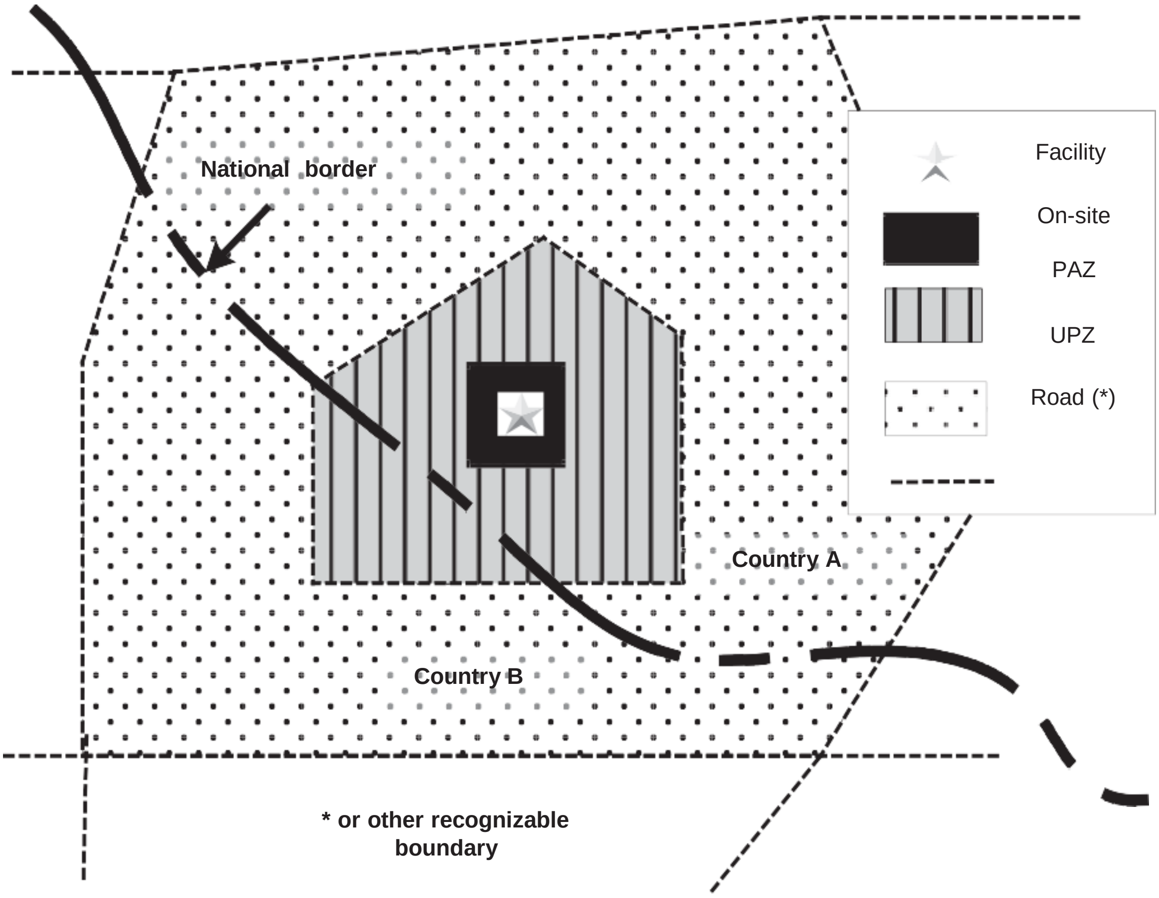

Fig. 11. Emergency zones

Facilities in threat categories I and II

Table 11 provides suggestions for the approximate radii of the emergency zones for facilities in threat categories I and II. The distances in Table 11 are suggested with due recognition of the great uncertainties involved and they should be revised by a factor of up to two during their application if necessary to meet local conditions.

The choice of the suggested radii represents a judgement of the distance from the site of the emergency for which it is reasonable to make advanced arrangements to ensure an effective response. In a particular emergency, protective actions may be warranted only in a small part of the zones. For the most serious emergencies, protective actions might need to be taken beyond the radii suggested.

The radius shown in Table 11 are suggestions on the basis of a general analysis. Each State may carry out an independent analysis to determine its own zone sizes that are appropriate in view of the specifics of the State, provided that the analysis:

a) addresses the full range of possible emergencies, including those of low probability, as required by the Requirements; and

b) is carried out with the goal of meeting the requirements for establishing these zones as established in the Requirements.

The sizes of the zones are shown in terms of the radius of a circle centred at the source of a potential release or criticality. However, the actual boundary of the zones should not be a circle but should be established to conform to physical and geographical features such as roads or rivers or to political boundaries, as illustrated in Figs 10 and 11. A discussion of the philosophy for establishing the zone size follows Table 12.

Table 11

Suggested radius of the inner cordoned area (safety perimeter) in a radiological emergency

Situation	Initial inner cordoned area (safety perimeter)
Initial — outside	
Unshielded or damaged potentially dangerous source[a]	Spill area (if a spill occurs) plus 30 m around
Major spill from a potentially dangerous source	Spill area plus 100 m around
Fire, explosion or fumes involving a potentially dangerous source	300 m radius
Suspected bomb (potential radiological dispersal device), exploded or unexploded	400 m radius or more to protect against an explosion
Initial — inside a building	
Damage, loss of shielding or spill involving a potentially dangerous source	The room affected and adjacent areas (including floors above and below)
Fire, suspected radiological dispersal device or other event involving a potentially dangerous source that can spread materials in the building (e.g. internal dispersion through the ventilation system)	Entire building and appropriate outside distance as indicated above
Based on OILs — following the initial determination	
Ambient dose rate of 100 μSv/h[b] 1000 Bq/cm^2 beta and/or gamma depositionc,[d] 100 Bq/cm^2 alpha depositiond	Wherever these levels are measured

a See Appendix III Safety Guide No. GS-G-2.1.
b The ambient dose rate is measured at 1 m above ground level for strong gamma emitters.
c These levels are not directly measured in the field and therefore OILs must be developed for the instruments to be used to determine if these levels of deposition are present.
d Deposition levels can only be assessed by a qualified radiological assessor.

Precautionary action zone (PAZ)

The PAZ, which only applies to facilities in threat category I, is the area within which arrangements should be made to implement precautionary urgent protective actions before or shortly after a major release with the aim of preventing or reducing the occurrence of severe deterministic effects[16].

Table 12

Suggested emergency zones and area sizes[a]

Facilities	Precautionary action zone (PAZ) radius[b,c]	Urgent protective action planning zone (UPZ) radius[d]
Threat category I facilities		
Reactors >1000 MW(th)	3–5 km	5–30 kme
Reactors 100–1000 MW(th)	0.5–3 km	5–30 kme
A/D2 from Appendix III is ≥105 [f]	3–5 km	5–30 kme
A/D2 from Appendix III is ≥104–105 [f]	0.5–3 km	5–30 kme
Threat category II facilities		
Reactors 10–100 MW(th)	None	0.5–5 km
Reactors 2–10 MW(th)	None	0.5 km
A/D2 from Appendix III is ≥103–104 [f]	None	0.5–5 km
A/D2 from Appendix III is ≥102–103 [f]	None	0.5 km
Fissionable mass is possible within 500 m of site boundary[g]	None	0.5–1 km

a The radius is the approximate default distance from the facility at which the boundary of the zone should be established. Variation by a factor of two or more during application is reasonable. A different distance should be used when this is substantiated by a detailed safety analysis.
b The suggested radii are the approximate distances for which the acute (2 day) dose to the bone marrow or lung could (with a very low probability) approach levels that are life threatening. A maximum radius of 5 km is recommended, as discussed elsewhere in this appendix. The source term (release) used for reactor emergencies is typical of that postulated for the range of low probability accidents that could potentially lead to severe deterministic effects off the site.
c The radii were selected on the basis of calculations performed with the RASCAL 3.0 computer model. For the purpose of the calculation, average meteorological conditions, no rain, a ground level release and an exposure for 48 hours to ground shine are assumed, and the centreline dose to a person outside for 48 hours is calculated.
d The suggested radii are the approximate distances for which the total effective dose for inhalation, cloud shine and ground shine for 48 hours will not exceed 1–10 times the GIL for evacuation, with a maximum radius of 5–30 km, as recommended for the reasons discussed elsewhere in this appendix.
e A distance of between 5 and 30 km may be considered reasonable if supported by a site specific analysis.
f Assuming that 10% of the inventory is released to the atmosphere.
g The radial distance (500 m) is the distance at which the GIL for evacuation is exceeded, on the assumption that the building containing the criticality (fissile material) does not provide
significant shielding and that the criticality results in 1019 fissions. This includes the dose due to external irradiation (gamma and neutron) and was calculated using the RASCAL 3.0 model.

The suggested sizes for the PAZ are based on expert judgement made in consideration of the following:

- Urgent protective actions taken before or shortly after a release within this radius will avert doses exceeding the thresholds for early death for the vast majority of major emergencies postulated for these facilities.
- Urgent protective actions taken before or shortly after a release within this radius will prevent doses exceeding the urgent protective action GILs for the majority of emergencies postulated for the facility.

[16] Safety Guide No. GS-G-2.1

- Dose rates that could be fatal within a few hours were observed at these distances during the Chernobyl accident.

The maximum reasonable radius for the PAZ is assumed to be 5 km because:

a) except for the emergencies with the most severe consequences, it is the distance limit out to which doses that would lead to early deaths are postulated;

b) it provides a reduction in dose by a factor of about ten in comparison with the dose on the site;

c) it is very unlikely that urgent protective actions will be warranted at a significant distance beyond this radial distance;

d) it is considered the practical limit of the distance to which substantial sheltering or evacuation can be promptly implemented before or shortly after a radioactive release; and implementing precautionary urgent protective actions to a larger radius might reduce the effectiveness of the actions for the people nearer the site who are at the greatest risk.

Urgent protective action planning zone (UPZ)

The UPZ, which applies to facilities in threat categories I and II, is the area where preparations are made to promptly shelter in place, to perform environmental monitoring and to implement urgent protective actions on the basis of the results of monitoring within a few hours following a release. The suggested sizes of the UPZ are based on expert judgement made in consideration of the following:

Threat category I facilities

These are the radial distances, studies suggest, out to which monitoring to locate and evacuate hot spots (due to deposition) within hours may be warranted to significantly reduce the risk of doses that would lead to early deaths in the emergencies with the most severe consequences postulated for power reactors.

At these radial distances there is a reduction by a factor of approximately ten in concentration (and thus risk) due to a release in comparison with the concentration at the PAZ boundary.

This distance provides a substantial base for the expansion of response efforts.

A distance of 5–30 km is assumed to be the practical limit for the radial distance within which to conduct monitoring and to implement appropriate urgent protective actions within a few hours. For average meteorological (dilution) conditions, beyond this radius, for most postulated emergencies with severe consequences the total effective dose to an individual would not exceed the urgent protective action GILs for evacuation.

Threat category II facilities

Atmospheric release

For average meteorological (dilution) conditions, beyond the UPZ radius, only the postulated emergencies with the most severe consequences would result in a total effective dose to an individual in excess of the urgent protective action GILs for evacuation.

Preparations within this radius provide a substantial base for the implementation of effective urgent protective actions beyond it, if needed.

A distance of 0.5 km was selected as the smallest radius, in consideration of possible wake effects caused by buildings.

Fissionable mass (criticality)

The radiological risk due to a criticality is dominated by the external dose due to gamma and neutron radiation.

Beyond this radius, most accidental criticalities would not result in a total effective dose to an individual in excess of the urgent protective action GILs for evacuation.

The off-site doses due to past criticality accidents have not warranted urgent protective actions beyond a distance of 0.5–1 km.

TAKING EARLY PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS

Early Phase Protective Actions

Immediately upon becoming aware that an incident is about to occur or has occurred that may result in exposure of the population, responsible authorities should make a preliminary evaluation to determine the nature and potential magnitude of the incident. This evaluation should determine whether conditions indicate a significant possibility of a major release and, to the extent feasible, determine potential exposure pathways, populations at risk, and projected doses. The incident evaluation and recommendations should then be presented to emergency response authorities for consideration and implementation.

In the early phase, there may be little or no data on actual releases to the environment and responders may have to rely on crude estimates of airborne releases. Decision time frames are short and preparation is critical to make prudent decisions when data are lacking or insufficient.

During the early phase, the sequence of events includes evaluation of conditions at the location of the incident, notification of responsible authorities, prediction or evaluation of potential consequences to the general public, recommendations for action and implementation of actions for the protection of the public (Fig. 12).

In the intermediate phase, dose projections used to support decisions about protective actions may be based on measurements of actual levels of environmental radioactivity and refined dose models, reducing the need for worst-case scenarios. When conditions warrant relocation of populations, the collection of extensive radiological and cost-of-cleanup data will be necessary to form the decision basis for cleanup and recovery of the affected areas.

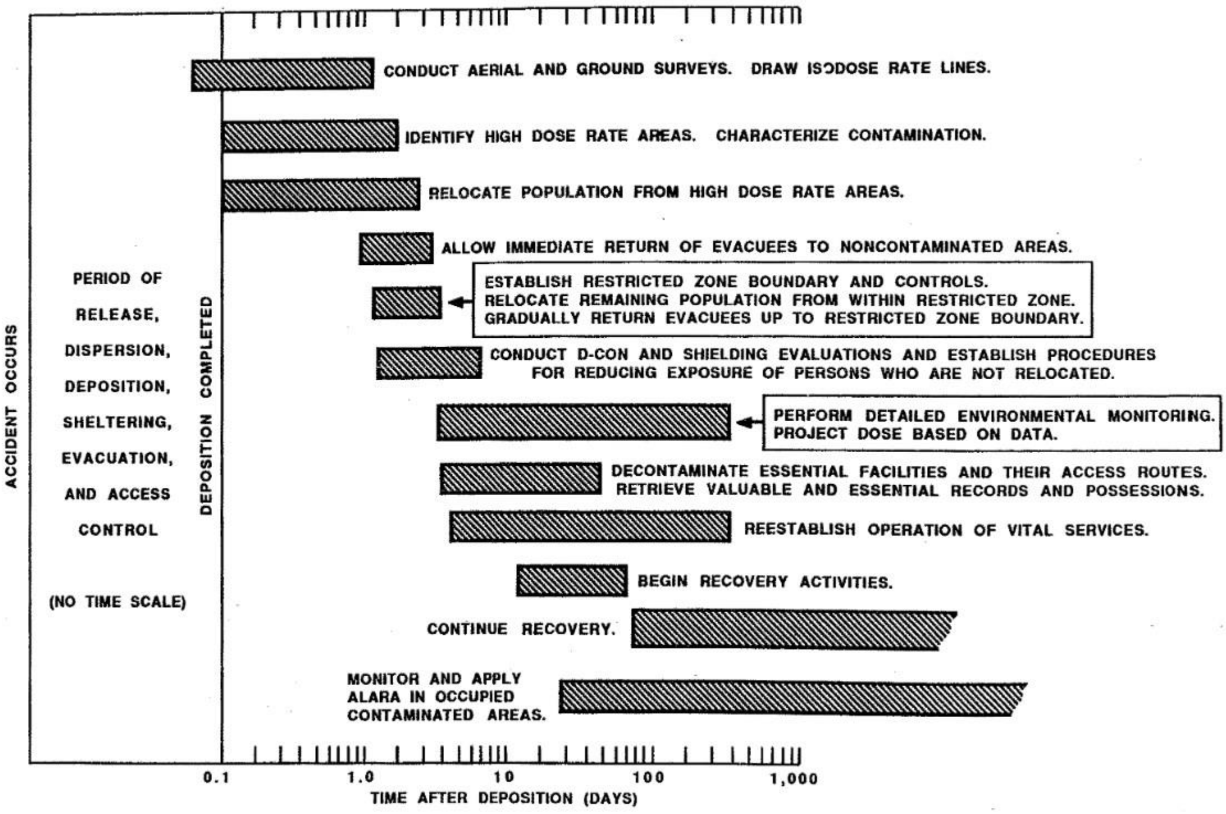

Fig. 12. Potential time frame of response to a nuclear incident

Early Phase – the beginning of a radiological incident for which immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions.

The principal requirements on taking urgent protective action covered in the Safety Requirements publication relate to:

Response

- the need to save lives;
- the need to prevent serious deterministic effects and avert doses;
- the need to modify protective actions as information becomes available;
- the discontinuance of a protective action when it is no longer justified.

Preparedness

- the establishment of optimized national intervention levels;
- the adoption of national guidelines for the termination of urgent protective actions;
- the provision of information to first responders about the urgency of saving lives and preventing serious injury;
- for facilities in threat category I or II, the arrangements for making and implementing decisions on actions to be taken off-site;
- the arrangements for the off-site officials to make protective action decisions promptly;
- the arrangements for the jurisdictions within the PAZ and/or UPZ to take urgent action promptly;
- for the operator of a facility in threat category I, II or III, the arrangements to ensure the safety of persons on site;
- for the operator of a facility in threat category I, II or III, the need to ensure the necessary means of communication is available.

The early phase – lasting hours to days – is the period beginning at the projected (or actual) initiation of a release when immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the release and the prognosis for worsening conditions.

When available, predictions of radiological conditions in the environment based on the condition of the source or actual environmental measurements may be used. Protective actions may be preceded by precautionary actions during the period.

The phases cannot be represented by precise periods of time – and may even overlap – but to view them in terms of activities, rather than time spans, can provide a useful framework for emergency response planning.

In the early phase, sheltering-in-place and evacuation are the principal protective actions. These actions are meant to avoid inhalation of gases or particulates in an atmospheric plume and to minimize external radiation exposures[17].

Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure from the plume or deposited radioactivity. Sheltering-in-place refers to the use of a readily available structure that will provide protection from exposure to the plume.

Sheltering-in-place is the action of staying or going indoors immediately.

Evacuation is appropriate when its risks and secondary effects are less severe than the risk of the projected radiation dose. Evacuation will be most effective in avoiding dose if completed before plume arrival.

In general, sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection. After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated by public officials.

[17] PAG Manual Protective action guides and planning for radiological incidents, 2017.

Administration of prophylactic drugs may be employed depending on the specific radionuclides released; in particular, KI, also called “stable iodine,” may be administered as a supplementary protective action in incidents involving the release of significant quantities of radioactive iodine. Some protective actions may begin prior to the release of radioactive material when there is advance notice.

To make decisions about rapid actions to protect the public in a radiological emergency, it is important to understand exposure pathways from airborne releases. It may also be necessary to make estimates about exposure patterns to make initial dose projections and determine whether protective actions are needed, before environmental monitoring is complete.

The guaidlines for evacuation or sheltering-in-place is a projected whole body dose of 1 to 5 rem (10 – 50 mSv) total effective dose (TED) over four days.

The decision to evacuate must weigh the anticipated radiation dose to individuals in the affected population against the feasibility of evacuating within a determined time frame and the risks associated with the evacuation itself. For example, evacuating a population of 50,000 carries with it a statistical risk of injury or death from transportation hazards or increased exposure.

Evacuation also takes time. In the case of an accident at an NPP, there will likely be time for an orderly and relatively safe evacuation. In the case of a fire or explosion of an RDD in an urban area, evacuating a large group of people could leave them exposed to the plume and actually increase radiation dose. Sheltering-in-place may be warranted in situations where evacuation poses a greater risk of exposure or physical harm.

In addition, there are actions that are advisable, but not associated with a numerical guidelines. For example, individuals should be instructed to cover airways (nose and mouth) with available filtering material when airborne radionuclides may be present. Decontamination is another protective action that may be utilized in the early phase and may include washing of contaminated individuals, removing contaminated clothing, and decontaminating surfaces of critical areas and objects. Further, in areas where airborne radioactivity is present but are not exceeded, officials can consider asking people to stay indoors to the extent practicable. In such cases, individuals are not prevented from carrying out necessary tasks (e.g., seeking medical care, purchasing food). Similar to actions used in major cities on high pollution days, these measures can be effective to reduce radiation doses when prolonged releases occur, as was the case for the Fukushima accident in Japan.

In cases where significant quantities of radioiodine may have been released, administration of the radioprotectant KI should be considered as a supplementary protective action if the projected child thyroid dose exceeds 5 rem (50 mSv).

The lower dose, which FDA adopted in 2001, is for protection of children based on early studies of Chernobyl exposure data. Of the age groups in ICRP 60 series (ICRP 1991), the one-year old age group is expected to be limiting for thyroid dose projections. Therefore, it is recommended that the one-year old age group thyroid dose be projected when considering the administration of prophylactic KI.

The choice of protective action will be based on the status of the incident site and the prognosis for worsening conditions. In the early phase, precautionary actions based on worst-case scenarios may be used before implementation of protective actions.

For example, in the case of RDD detonation, governments may instruct affected populations to shelter-in-place as a precautionary action while radiation levels are being measured to determine appropriate protective actions.

Officials should plan for rapid broadcast and dissemination of protective action orders to the public.

Some critical infrastructure/key resources or lifesaving missions may arise in later phases, however, for which the emergency worker guides would apply. Reoccupancy may be allowed under dose constraints acceptable to the community. The term reoccupancy refers to households and communities moving back into relocation areas where the cleanup process is still ongoing, based on radiation levels acceptable to those communities.

For the protection of responders on-site during the long-term phase, the reference level should not exceed 20 mSv year. For the protection of responders off-site, the reference level should be selected within the lower half of the recommended band of 1–20 mSv year^{-1}.

For the long-term phase, the reference level should be selected in the lower half of the recommended band of 1–20 mSv year^{-1} for existing exposure situations, taking into account the actual distribution of doses in the population and the societal, environmental, and economic factors influencing the exposure situation. The objective of optimisation of protection is a progressive reduction in exposure to levels towards the lower end of the band, or below if possible. ICRP reiterates that the process for selecting the reference level should result from a careful balance of many inter-related factors, including the sustainability of social life and economic activities, as well as the quality of the environment, and should appropriately reflect the views of all relevant stakeholders.

Depending on the accident scenario, this could take several years, or even decades, because exposure of people living and working in contaminated areas largely depends on their habits and living conditions, which cannot be strictly controlled. It is therefore not possible to guarantee that all individual doses will be kept below the reference level in the long term. Selection of the reference level to manage the long-term phase is a complex decision that should be informed by societal and ethical value judgements. Due to this complexity, ICRP recommends that stakeholders who will be confronted with the situation should be involved as much as possible when selecting the value of the reference level.

Decisions on the adaptation of urgent protective actions and the implementation of early protective actions are taken on the basis of increasingly more detailed information and better knowledge of the exposure situation.

Decontamination and focused cleanup techniques can range from simple actions such as the scrubbing and flushing of surfaces with uncontaminated water to the removal and disposal of soil and contaminated debris.

In addition, washing the body and changing clothing as soon as possible after significant exposure to a radioactive plume of any composition may be recommended protective actions. Changing of clothing is recommended to provide protection from particulate materials deposited on the clothing, as well as to minimize the spread of contamination.

Keeping projected doses below the 0.5 rem (5 mSv) – in the second and subsequent years – may be achieved through the decay of shorter half-life radioisotopes, through environmental decontamination and cleanup efforts or through other means of controlling public exposures, such as limiting access to certain areas.

Workers and members of the public may be allowed to re-enter a relocation area for tasks related to critical infrastructure and key resources, to care for animals and to assess the condition of closed zones. By the intermediate phase when relocation has been implemented, it is likely that no more lifesaving missions would be needed.

When available, predictions of radiological conditions in the environment based on an estimate of the source or actual environmental measurements may be used. Nuclear facilities, for example, have continuous, real-time radioactive effluent monitoring capabilities to monitor radioactive material released to the environment and may have a network of off-site measurement stations.

Early protective actions should be implemented within days or weeks to be effective. They can be long lasting, even after the emergency (e.g. temporary relocation). In no case should urgent protective actions and early protective actions based on the generic criteria cause more detriment than they avert. Event specific conditions may warrant modification of the generic criteria.

Reference levels are used as guiding values to select protective actions. At the beginning, a fraction of the individual exposures may be above the reference level. A priority should be to identify the most exposed people in order to prevent or reduce their exposure. The protective actions should progressively reduce the number of people receiving exposures above the reference level.

When conditions evolve and the dose distribution changes, it may be appropriate to re-evaluate the reference level.

Dose calculations are made using the dose parameter (DP) and derived response level (DRL) calculation methods referenced in standarts. Emergency response organizations are encouraged to use the most current, applicable tools and methods for implementing the protective actions.

The corresponding protective actions for response during the early phase of an incident are summarized in Table 13.

Table 13

Summary Table for **Protective Action**, Guidelines, and Planning Guidance for Radiological Incidents[a]

Phase	Protective Action Recommendation	PA, Guideline, or Planning Guidance
Early Phase	Sheltering-in-place or evacuation of the public[b]	**PA**: 1 to 5 rem (10 to 50 mSv) projected dose over four days[c]
	Supplementary administration of prophylactic drugs – KI[d]	**PA**: 5 rem (50 mSv) projected child thyroid dose[e] from exposure to radioactive iodine
	Limit emergency worker exposure (total dose incurred over entire response)	**Guideline**: 5 rem (50 mSv)/year (or greater under exceptional circumstances)[f]
Intermediate Phase	Relocation of the public	**PA**: $\geq$ 2 rem (20 mSv) projected dose[c] in the first year 0.5 rem (5 mSv)/year projected dose in the second and subsequent years
	Apply simple dose reduction techniques	**Guideline**: < 2 rem (20 mSv) projected dose[c] in the first year
	Food interdiction[g]	**PA**: 0.5 rem (5 mSv)/year projected whole body dose, or 5 rem (50 mSv)/year to any individual organ or tissue, whichever is limiting
	Drinking water	**PA:** 100 mrem (1 mSv or 0.1 rem) projected dose, for one year, to the most sensitive populations (e.g., infants, children, pregnant women and nursing women); 500 mrem (5 mSv or 0.5 rem) projected dose, for one year, to the general population
	Limit emergency worker exposure (total dose incurred over entire response)	**Guideline**: 5 rem (50 mSv)/year
	Reentry	**Guideline**: Operational Guidelines[h] (stay times and concentrations) for specific reentry activities (see Section 4.5)
Late Phase	Cleanup[i]	**Planning Guidance**: Brief description of planning process
	Waste Disposal	**Planning Guidance**: Brief description of planning process

[a] This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA).

[b] Should begin at 1 rem (10 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.

[c] Projected dose is the sum of the effective dose from external radiation exposure (e.g., groundshine and plume submersion) and the committed effective dose from inhaled radioactive material.

[d] Provides thyroid protection from radioactive iodines only. See the complete 2001 FDA guidance, "Potassium Iodide as a Thyroid Blocking Agent in Radiation Emergencies" (FDA 2001).

[e] Thyroid dose. The one-year old age group is expected to receive the largest dose to the thyroid from exposure to radioactive iodine. Therefore, it is recommended that the one-year old age group is considered when considering the administration of prophylactic KI.

[f] When radiation control options are not available, or, due to the magnitude of the incident, are not sufficient, doses to emergency workers above 5 rem (50 mSv) may be unavoidable and are generally approved by competent authority. Each emergency worker should be fully informed of the risks of exposure they may experience and trained, to the extent feasible, on actions to be taken. Each emergency worker should make an informed decision as to how much radiation risk they are willing to accept to save lives.

g For more information on food and animal feeds guidance, the complete FDA guidance (FDA 1998).

[h] For extensive technical and practical implementation information please see "Preliminary Report on Operational Guidelines Developed for Use in Emergency Preparedness and Response to a Radiological Dispersal Device Incident" (DOE 2009).

[i] This cleanup process does not rely on and does not affect any authority, including the Comprehensive Environmental Response.

Exposure Pathways from Airborne Releases

During the early phase of an incident, there are three main exposure pathways from airborne releases:

Direct exposure to radioactive materials in an atmospheric plume. The contents of such a plume will depend on the source of radiation involved and conditions of the incident. For example, in the case of an incident at an NPP, the plume may contain radioactive noble gases, radioiodines, and radioactive particulate materials. Many of these materials emit gamma radiation that can expose people in the vicinity of the passing plume.

Inhalation of radionuclides from immersion in a radioactive atmospheric plume and inhalation of ground-deposited radionuclides that are resuspended into a breathing zone. Inhaled radioactive particulates, depending on their solubility in body fluids, may remain in the lungs or move via the bloodstream to other organs, prior to elimination from the body. Some radionuclides become concentrated in a single body organ, with only small amounts going to other organs. For example, a significant fraction of inhaled radioiodines will move through the bloodstream to the thyroid gland.

Deposition of radioiodine and particulates from a radioactive plume. Deposited materials can continue to emit "groundshine" (e.g., beta and gamma radiation) after the plume has passed causing continued exposure to skin and internal body organs.

A plume may deposit materials on surfaces, posing a risk of longer-term exposures via ingestion, direct external exposure, and inhalation pathways. If the release contains large quantities of radioactive iodines or particulates, the resulting long-term exposure to this "groundshine" can be more significant than external exposure from the passing plume if the exposure time to the ground contamination is long in comparison to the plume passage time. The early phase PAGs assume four days of exposure to ground contamination to address this possibility. Doses from groundshine can be readily measured by field monitoring teams dispatched at the onset of a significant radioactive release. Holding a detector probe horizontal and three feet (approximately one meter) above the contaminated surface provides a direct measurement that can be used to approximate groundshine dose. Such assessments can confirm dose projections based upon effluent release data and the adequacy of protective actions in the early phase.

More detailed analyses (e.g., isotopic) would be needed to support long-term dose projections in the intermediate phase. Doses for groundshine can be calculated during the intermediate phase. Exposure pathways that contribute less than 10 percent to the total dose incurred need not be considered during the early phase.

Immediately upon becoming aware that an incident is about to occur or has occurred that may result in exposure of the population, responsible authorities should make a preliminary evaluation to determine the nature and potential magnitude of the incident. This evaluation should determine whether conditions indicate a significant possibility of a major release and, to the extent feasible, determine potential exposure pathways, populations at risk, and projected doses. The incident evaluation and recommendations should then be presented to emergency response authorities for consideration and implementation.

During the early phase, the sequence of events includes evaluation of conditions at the location of the incident, notification of responsible authorities, prediction or evaluation of potential consequences to the general public, recommendations for action and implementation of actions for the protection of the public.

In the intermediate phase, dose projections used to support decisions about protective actions may be based on measurements of actual levels of environmental radioactivity and refined dose models, reducing the need for worst-case scenarios. When conditions warrant relocation of populations, the collection of extensive radiological and cost-of-cleanup data will be necessary to form the decision basis for cleanup and recovery of the affected areas.

The most commonly considered early protective actions within a protection strategy are:

a) evacuation
b) sheltering-in-place
c) relocation;
d) long term restrictions on the consumption of food, milk and drinking water;
e) restrictions on the use of commodities that have the potential to result in significant exposures;
f) actions to prevent inadvertent ingestion and to control the spread of contamination (including access control for areas where evacuation or relocation is implemented); and
g) decontamination of areas or commodities to further reduce the individual doses.

Decisions on the adaptation of urgent protective actions and the implementation of early protective actions are taken on the basis of increasingly more detailed information and better knowledge of the exposure situation.

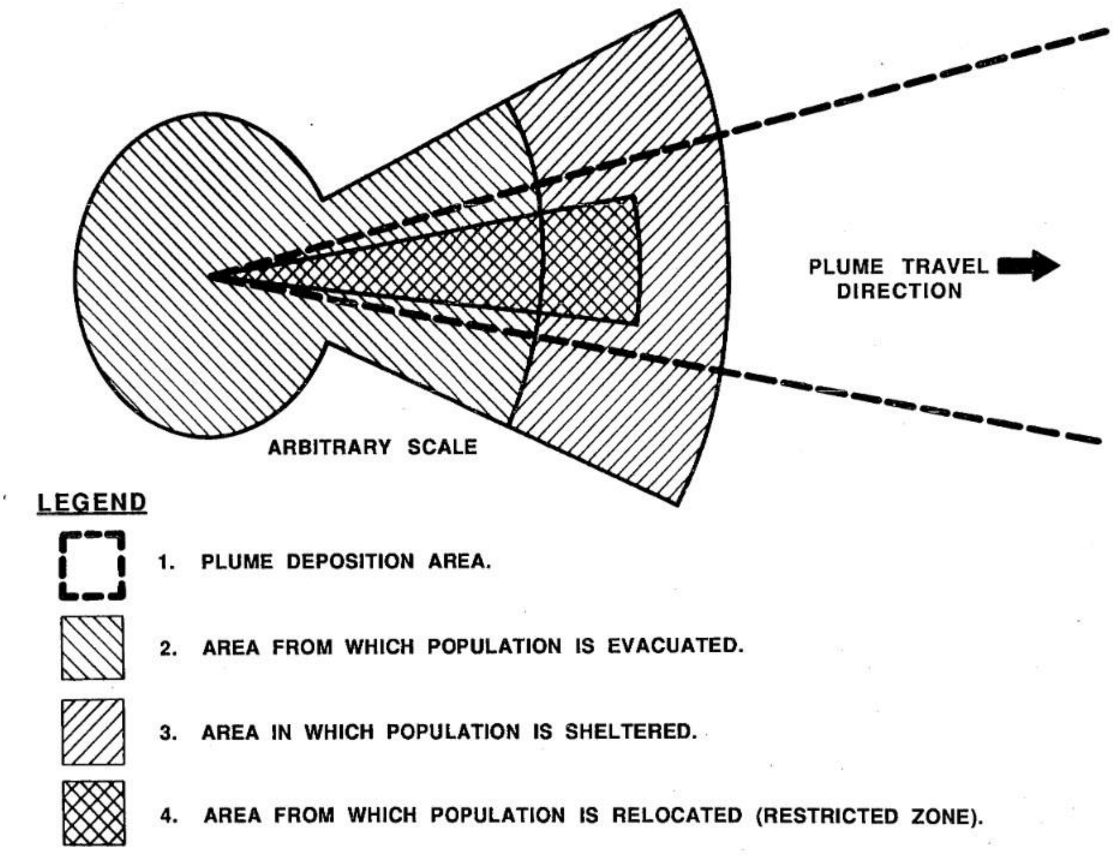

Fig. 13. Response areas

Thyroid Based Evacuation

Regarding sensitive subpopulations, child thyroid doses typically are about twice as high as adult thyroid doses. The former range recommended for thyroid dose-based evacuation (5 to 25 rem adult thyroid dose) is well covered by projections of whole body dose, with evacuation recommended at 1 to 5 rem (10 to 50 mSv) adult TED. The conservatism built into the levels when they were set results in an appropriate level of dose avoidance for the whole community, including all age groups, for an emergency. Planners should consider instituting public messaging templates in advance to address concerns the public may have about how protective the recommendations are for all members of an impacted community.

This set of recommendations does not preclude an emergency manager from setting local or state protective action guidelines for actions based on specific organ or age group dose levels, as warranted by specific needs of that community.

Table 14

Protective Actions for the Early Phase of a Radiological Incident[a]

Protective Action Recommendation	Level	Comments
Sheltering-in-place or evacuation of the public[b]	1 to 5 rem (10 to 50 mSv) projected dose over four days[c]	Evacuation (or, for some situations, sheltering-in-place) should be initiated when projected dose is 1 rem (10 mSv).
Supplementary administration of prophylactic drugs – KI[d]	5 rem (50 mSv) projected child thyroid dose[e] from exposure to radioactive iodine	KI is most effective if taken prior to exposure. May require approval of state medical officials (or in accordance with established emergency plans).

[a] This guidance does not address or impact site cleanups occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program.

[b] Should begin at 1 rem (10 mSv) if advantageous except when practical or safety considerations warrant using 5 rem (50 mSv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.

[c] Projected dose is the sum of the effective dose from external radiation exposure (e.g., groundshine and plume submersion) and the committed effective dose from inhaled radioactive material.

[d] Provides thyroid protection from radioactive iodines only.

[e] Thyroid dose. The one-year old age group is expected to receive the largest dose to the thyroid from exposure to radioactive iodine. Therefore, it is recommended that the one-year old age group is considered when considering the administration of prophylactic KI.

Evacuation vs. Sheltering-in-Place

Evacuation and sheltering-in-place provide different levels of dose reduction from the principal exposure pathways: direct gamma exposure and inhalation. Both sheltering-in-place and evacuation may be implemented during the same response in different areas or timeframes. Evacuation, if completed before plume arrival, can be 100 percent effective in avoiding radiation exposure. A decontamination station, with simple decontamination actions, may need to be collocated at shelters during the pre-evacuation period. This may reduce the spread of contamination and provide for greater protection during evacuation. Medical stations should also be collocated at shelters during the pre-evacuation period to ensure simple triage capabilities are met and to manage the distribution of prophylactic drugs. The effectiveness of evacuation will depend on many factors, such as how rapidly it can be implemented and the nature of the incident. For incidents where the principal source of dose is inhalation, evacuation could increase exposure if it is implemented during the passage of a short-term plume, because the air inside a vehicle rapidly equalizes with the outside air even when all of the windows and vents are closed.

When dose projections are at levels less than 1 rem (10 mSv) over the first four days, evacuation is not recommended due to the associated risks of moving large numbers of people.

Sheltering-in-place is a low-cost, low-risk protective action that can provide protection with an efficiency ranging from zero to almost 100 percent, depending on the type of release, the type of shelter available, the duration of the plume passage, and climatic conditions. Because of these advantages, planners and decision-makers may consider implementing sheltering-in-place when projected doses are below 1 rem (10 mSv) over the first four days.

Sheltering-in-place may be preferred for special populations (e.g., those who are not readily mobile) as a protective action at projected doses of up to 5 rem (50 mSv) over four days. When environmental, physical, or weather hazards impede evacuation, sheltering-in-place may be justified at projected doses up to 5 rem (50 mSv) for the general population (and up to 10 rem (100 mSv) for special populations). It is also comparatively easy to communicate with populations that have sheltered-in-place. Dose projections use a four-day exposure duration, but sheltering-in-place duration is intentionally not specified. Incident- specific decisions must be made to determine how long people should shelter-in-place.

Selection of evacuation or sheltering-in-place is far from an exact science, particularly in light of time constraints that may prevent thorough analysis at the time of an incident. The selection process should be based on realistic or “best estimate” dose models and should take into account the unavoidable dose incurred during evacuation and potential failure scenarios for sheltering-in-place (e.g., leaking ventilation system).

Advance planning and exercises can facilitate the decision process. In a commercial NPP incident, early decisions should be based on information from the response plans for the emergency planning zone (EPZ) and on actual conditions at the nuclear facility. For transportation accidents, RDDs, INDs and other incident scenarios for which EPZs are not practicable, best estimates of dose projections should be used for deciding on evacuation, sheltering- in-place or a combination thereof.

Sheltering-in-place should be preferred to evacuation whenever it provides equal or greater protection.

Sheltering-in-place followed by informed evacuation may be most protective.

The following is a summary of planning guidance for evacuation and sheltering-in-place:

- Evacuation may be the only effective protective action close to the plume source.
- Evacuation will be most effective if it is completed before arrival of the plume.
- Evacuation may increase exposure if carried out during the plume passage.
- Evacuation is appropriate for protection from groundshine in areas with high exposure rates from deposited radioactive materials when suitable shelter is not available.
- Sheltering-in-place may be appropriate for areas not designated for immediate evacuation:
    - It may provide protection equal to or greater than evacuation for rapidly developing releases(e.g., RDDs) if followed by evacuation.
    - It positions the public to receive additional instructions.
    - Since it may be implemented rapidly, sheltering-in-place may be the protective action of choice (followed with evacuation when feasible) if rapid evacuation is impeded by:
        - severe environmental conditions (e.g., severe weather or floods);
        - uncertainty about contamination levels along routes;
        - health constraints (e.g., patients and workers in hospitals and nursing homes);
        - long mobilization times that may be associated with certain individuals, such as industrialand farm workers, or prisoners and guards; or
        - physical constraints to evacuation (e.g., inadequate roads or blockage

due to debris).

- If a major release of radioiodine or particulate materials occurs, inhalation dose may be a controlling criterion for protective actions:
  - Breathing air filtered through common household items (e.g., folded handkerchiefs or towels) may help reduce exposures.
  - After confirmation that the plume has passed, continued sheltering-in-place should be re-evaluated. People should remain sheltered until receiving official notice about leaving high exposure areas to avoid exposure to deposited radioactive material. Shelters may be opened to vent any airborne radioactivity trapped inside.

Advance planning is essential to identify potential problems that may occur in an evacuation. Aspects of planning as contributing to efficiency and effectiveness of evacuation:

- High level of cooperation among agencies.
- Use of multiple forms of emergency communications.
- Community familiarity with alerting methods, the nature of the hazard, and evacuation procedures.
- Community communication.
- Well-trained emergency workers.

The NRC 2005 (USA) study included an evaluation of 50 incidents of public evacuation involving 1,000 or more people. The evacuations studied were initiated in response to natural disasters, technological hazards, and malevolent acts occurring between January 1, 1990 and June 30, 2003. The report indicated that public familiarity with alerting methods and door-to-door notification were statistically significant factors for the efficiency of evacuation. The report also indicated that many communities are making improvements to response capabilities by modernizing communication systems, improving traffic flow, local education awareness, and developing interagency and cross-boundary coordination plans.

Large or small population groups can be evacuated effectively with minimal risk of injury or death. In the NRC report, only six of the 50 cases studied involved deaths from the hazard and of those six, only one involved death from the evacuation itself (NRC 2005).

However, in 2005, not long after this report was published, the gulf coast of the United States was hit by a series of hurricanes that resulted in the evacuation of approximately 5 million people. During the evacuation that accompanied Hurricane Rita in Houston, Texas, at least 106 people were reported to have died as a direct result of the evacuation. It is estimated that at least two-thirds of the evacuees did not need to evacuate but did so because of poor communication, fear, and poor traffic management (NRC 2008).

In a study of 230 mass evacuations in the U.S. ("Identification and Analysis of Factors Affecting Emergency Evacuations" NUREG/CR-6864 (NRC 2005)) only six cases involved deaths from the hazard itself, and of these six, only one case involved deaths during the evacuation itself. Only two cases involved injuries during the evacuation. Traffic issues, such as traffic congestion, were reported in 28 percent of the evacuation cases studied. However, traffic accidents occurred in only 8 percent of the cases.

During the tsunami and nuclear disaster response in Japan in 2011, over 1,000 deaths occurred during evacuations, primarily among elderly hospital patients being moved from areas without power.

Compounded disaster conditions including aftershocks, widespread power outages, and radiation releases led to prolonged transit along routes extended to avoid hazards.

The emergency planning process for radiological incidents should include effective traffic management plans and communications plans, including pre-scripted messages, provisions for evacuation of special needs populations, such as children in schools and child care facilities, people in institutions, and people who have impaired mobility or lack personal transportation.

The degree of protection provided by structures is affected by factors such as attenuation of gamma radiation (shielding) by structural components (the mass of walls, ceilings, etc.) and outside/inside air exchange rates (see Figure 14). The use of large structures, such as shopping centers, schools, churches and commercial buildings, as collection points during evacuation mobilization will generally provide greater protection against gamma radiation than use of small structures. As with evacuation, delay in taking shelter during plume passage will result in higher exposure to radiation.

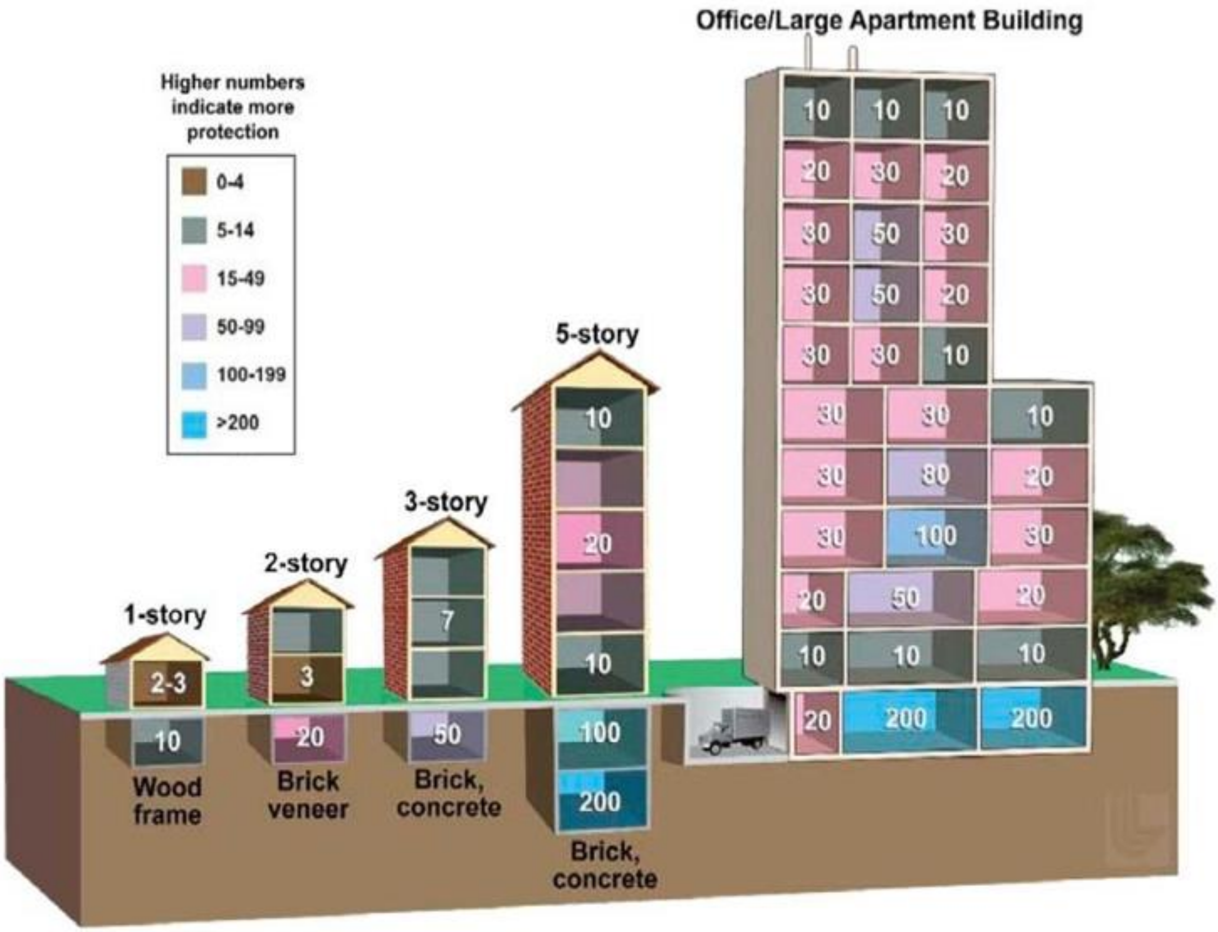

Fig. 14. Exposure Reduction from External Radiation from Nuclear Fallout
as a function of Building Type and Location

The numbers represent dose reduction factors. A dose reduction factor of 10 indicates that a person in that area would receive 1/10th of the dose of a person in the open. A dose reduction factor of 200 indicates that a person in that area would receive 1/200th of the dose of a person out in the open.

The protection factors in this figure are specific to nuclear detonation fallout, but the variations in factors throughout typical buildings may be informative for other airborne radiological releases.

Dose Projection during the Early Phase

The calculation of projected doses should be based on realistic dose models, to the extent practicable. Public protection decisions should be based upon the dose that can be avoided (i.e., avoidable dose) by taking some protective action (e.g., evacuation, sheltering-in-place). Unavoidable dose or doses incurred before the start of the protective action being considered generally should not be included in evaluating the need for protective action. Similarly, doses that may be incurred at later times than those affected by the specific protective action should not be included. As noted earlier, the projection of doses in the early phase needs to include only those exposure pathways that contribute a significant fraction (i.e., more than 10 percent) of the dose to an individual.

In the early phase of an incident, parameters other than projected dose may provide a more appropriate basis for decisions to implement protective actions. When a facility is operating outside its design basis and a substantial release to the environment has started, or is imminent but has not yet occurred, data adequate to directly estimate the projected dose may not be available. Emergency response plans should anticipate specific conditions at the source of a potential release and the possible consequences off-site. Emergency response plans for NPPs and facilities should make use of emergency action levels (EALs), based on in-plant conditions, to trigger notification and initial protective action recommendations to off- site officials. Once the initial protective actions have been implemented, accident assessment should continue. Although initial assessments may be uncertain, the subsequent assessments will be less uncertain as additional information on facility condition and prognosis, effluent radiation monitoring data and environmental data become available. The results of these continuing radiological assessments, including dose projections, should be used as the basis for refining the initial protective actions. In the case of transportation accidents, an RDD or IND, or other incidents that are not related to a facility, it may not be practicable to establish EALs.

Doses that may be incurred from ingestion of food and water, long-term radiation exposure (i.e., longer than four days), radiation exposure to deposited radioactive materials, or long-term inhalation of resuspended materials are chronic exposures for which neither emergency evacuation nor sheltering-in-place are appropriate protective actions. PAGs for the intermediate phase cover these exposure pathways.

Considerations for Potassium Iodide (KI)

For example in USA, FDA updated its guidance on the use of KI, also called “stable iodine,” as a thyroid blocking agent during radiological emergencies in 2001 (FDA 20018 and FDA 20029). FDA based these dose recommendations on a review of the thyroid cancer data from the Chernobyl reactor accident of April 1986 and the experience of Poland in administering KI following the Chernobyl release (FDA 2001).

However, FDA understands that a KI administration program that sets different projected thyroid radioactive exposure thresholds for treatment of different population groups may be logistically impractical to implement during a radiological emergency. In such cases, FDA recommends that KI be administered to both children and adults at the lowest intervention threshold (i.e., >5 rem (50 mSv) predicted internal thyroid exposure in children (FDA 2002). The one-year old age group thyroid dose is expected to be limiting. Therefore, it is recommended that the one-year old age group thyroid dose is projected when considering the administration of prophylactic KI. See Table for a summary of recommended doses of KI for different risk groups.

Regarding dosage of KI, FDA’s guidance adheres to principles of minimum effective dose and therefore recommends graded dosing according to age (and thus, in effect, body size). There is ample evidence that the recommended doses, as well as higher doses (e.g., up to 130 milligram), will effectively block thyroidal uptake of radioactive iodine if taken in advance of exposure. Furthermore, particularly among school-age children, higher milligram (mg) doses are extremely safe. However, FDA continues to emphasize attention to KI dosing in infants. Excess iodine intake can lead to transient iodine-induced hypothyroidism. Individuals who are intolerant of KI at protective doses, as well as neonates (i.e., a newborn infant, especially an infant less than one month old) and pregnant or lactating women, should be given priority with regard to other protective measures (i.e., sheltering, evacuation, and control of the food supply). In summary, if local emergency planners conclude that graded dosing is logistically impractical, FDA believes that for populations at risk for radioiodine exposure, the overall benefits of taking up to 130 mg of KI instead of the lower doses recommended for certain age groups far exceed the small risks of overdosing. However, where feasible, adherence to FDA guidance should be attempted when dosing infants (FDA 2002).

Note that KI is effective only against uptake of radioiodine, and is best taken prior to or just after exposure. The protective effect of a single dose of KI lasts approximately 24 hours. It should be administered as directed by state/local health officials until the risk of significant exposure to radioiodine (either by inhalation or ingestion) no longer exists (i.e., once the plume has passed). KI is a supplemental action, secondary to evacuation or sheltering. It should not be used as a substitute for evacuation or sheltering-in-place. Many communities do not use KI.

It should be noted that adults over 40 years of age need to take KI only in the case of a projected large internal radiation dose to the thyroid (>500 rem (5 Sv)) to prevent hypothyroidism which could lead to lifelong dependence on thyroid hormone replacement therapy. Thyroid irradiation in adults over 40 years of age is associated with an extremely low incidence of cancer (FDA 2001).

Some people should not take KI. As a rule, individuals with known allergy to iodine or with pre-existing thyroid disease (e.g., Graves' disease, thyroid nodules, Hashimoto's thyroiditis) that might predispose them to adverse reactions should avoid KI. Allergies to iodine and to shellfish are not related. People allergic to shellfish need not worry about cross reactions with KI.10

Observations

By definition, facilities within threat categories I and II are such where on-site events are postulated that could give rise to doses to people off the site that warrant urgent protective actions. Urgent protective actions include: evacuation, substantial shelter, iodine thyroid blocking and restricting consumption of food and water that could be contaminated. The Chernobyl accident, in particular, necessitated urgent actions off-site. The TMI accident could have led to significant doses off-site if the containment had not retained the radioactive material that had been released due to the melting of the core.

In the event, precautionary evacuation of some people was undertaken. Precautionary evacuation of the local population was also undertaken during the Tokaimura accident.

Some local officials have been reluctant to order an evacuation because they believed incorrectly that it would cause panic and numerous traffic fatalities. However, nearly fifty years of research on major evacuations (including those in response to serious radiation emergencies, release of a toxic chemical, the discovery of an unexploded World War II bomb, hurricanes) has shown that evacuations are relatively common and can be undertaken without panic and increased risk of traffic fatalities.

The experience from the evacuations that took place in response to hurricanes Katrina and Rita, which involved large populations, demonstrated the importance of careful management of the ensuing traffic flow and the provision of the necessary vehicles.

At TMI, two days after the core had melted, pregnant women and preschool aged children were advised to leave the area within a 5-mile radius. Approximately ten times as many people evacuated as were specifically advised to do so.

Much of this was due to confusing and conflicting information about the seriousness of the accident, as well as to expectations that there would be further evacuations later. At TMI, the protective action was aimed at a subgroup of the population (i.e. pregnant women and pre-school children). The authorities, however, failed to explain that the purpose of evacuating pregnant women was in order to protect the foetus. As a consequence, women of child-bearing age and families with infants also tended to evacuate.

The precautionary actions in the TMI accident were by no means complete. If the containment had failed, then substantial exposure of members of the public would have occurred. The high radiation levels within the containment should have indicated the need for more substantial precautionary actions. The USA Nuclear Regulatory Commission (NRC) inquiry found it would have been prudent to recommend precautionary evacuation at about the time the core was being damaged because 'the containment building was …filling with intensely radioactive gas and vapours, leaving the nearby public protected by only one remaining barrier, the containment, a barrier with a known leak rate that needed only internal pressure to drive the leakage'. The authorities had not, however, adequately identified the off-site risk areas before the accident occurred. Consequently, they had difficulty determining the distance from the plant within which evacuation should be carried out. This uncertainty on the part of the authorities became evident to the public and it was this that undermined public confidence in the authorities' competence, and thus made local residents less inclined to trust the authorities' protective action recommendations.

Studies and experience also show that releases into the atmosphere during severe emergencies at threat category I and II facilities are unpredictable. They can occur via an unmonitored release route and can begin within minutes after core damage.

Consequently, facility operators cannot predict with certainty the occurrence of a major radioactive material release, the magnitude and duration of any such release, or its radiological consequences. However, studies also show that taking precautionary protective actions (such as evacuation, substantial shelter, iodine thyroid blocking and restricting consumption of food and water that may be contaminated) promptly upon the detection of conditions in the facility that might lead to fuel being damaged (uncovered) will greatly reduce the off-site consequences. These precautionary protective actions should be followed by prompt monitoring after a release and further implementation of urgent protective actions based on the results of the monitoring.

Evacuation has been shown to be the most effective protective action for protection of those near by the facility if it can be implemented relatively quickly.

Sheltering within buildings is an appealing protective action because it can reduce the risk to people and avoids the disruption caused by evacuation. However, the effectiveness of sheltering to protect against an airborne release of radioactive material varies and depends on the structure of the buildings. In general, only large masonry buildings and specially prepared shelters provide significant protection. Its effectiveness also requires the occupants to seal the structure and shut off any ventilation systems before the plume arrives and to ventilate the structure as soon as possible after the plume has passed. There is, however, some evidence that people do not believe sheltering would be effective. Other research indicates that at least 50% of those advised to shelter in-place during a toxic chemical release evacuated instead.

The use of stable iodine can substantially reduce the thyroid dose from radioiodine if taken before or shortly after intake. During the Chernobyl accident, the Polish authorities distributed 17.5 million doses of stable iodine that caused serious short duration side effects in only two adults with known iodine sensitivity. A joint IAEA/WHO Technical Meeting held in September 2001 agreed that 'the administration of stable iodine to the public is an effective early measure for the protection of the thyroid to prevent deterministic effects and to minimize stochastic effects for persons of any age.

However, it is primarily intended for the protection of children and the embryo or foetus'. The cases of radiation induced thyroid cancer that occurred subsequent to the Chernobyl accident were due to the doses of internal exposure from consumption of milk and leafy vegetables contaminated with I-131. The vast majority of these radiation-induced cancers occurred among people residing at the time of the accident at distances more than 50 km from the plant; excess cancers were detected also among those residing at distances more than 300 km away. These radiation-induced cancers could have been prevented if the authorities had instructed people not to drink milk until the supplies had been shown to be free of I-131 contamination. Alternatively, people could have been given stable iodine prior to drinking the contaminated milk. However, this approach would have required the authorities to have available millions of doses of stable iodine and distribute them rapidly to those in the contaminated area. In addition, authorities would have had to convince the affected population of safety of stable iodine.

It is very difficult, if not impossible, to provide real time predictions of the off-site impact of a severe atmospheric release as a basis for undertaking urgent protective action, following an accident in a facility in threat category I or II. This is not only because of the limited data available, but also because tests and experience have shown that computer dose projections are not capable of providing a sufficiently timely or accurate basis for taking protective action at an early stage for areas near the facility. Nevertheless, the instrumentation used in facilities in threat categories I and II can, in most cases, detect the onset of severe accident conditions in the facility in time for the operators to provide a warning to initiate protective action before or shortly after a release. However, protective actions may not be undertaken quickly if the emergency plans lacked systems for taking decisions rapidly that coordinate with the offsite organizations.

When an emergency occurs within a facility, prompt detection of high radiation levels (e.g. with radiation/criticality alarms) and immediate evacuation, in accordance with prior training, has saved lives. Immediate search and rescue operations are sometimes required on site. Such operations have been performed under very hazardous conditions while the rest of the facility staff conducted other emergency operations. Rescue efforts are typically conducted by those nearby and may divert attention and effort from other emergency response tasks if they have not been integrated into the response plan.

Conclusions

These lessons demonstrate the importance of:

− prompt action being taken at the time of an emergency to prevent people from receiving high doses, which in turn, avoids the expensive medical treatment (e.g. for radiation-induced injuries or thyroid cancers) that may otherwise be necessary;

− for facilities within threat categories I and II, taking action based on plant conditions, rather than on dose projections derived from atmospheric release data or environmental monitoring;

− establishing, in advance, criteria for action to protect the public for facilities within threat categories I and II and for activities within threat category IV, thereby avoiding ad hoc decisions;

− the emergency plans containing these criteria for urgent protective action to be coordinated with all the authorities involved in responding to the emergency.

The lessons also indicate that:

− concerns about possible panic and traffic risks should not prevent the institution from undertaking evacuation to protect the public;

− administration of stable iodine needs to be done rapidly if it is to be effective in preventing the uptake of radioiodine by the thyroid, but that this may pose difficult logistical problems if the affected population is large;

− the preferred protective action upon the detection of a severe emergency (general emergency), in threat category I or II, is timely evacuation, iodine thyroid blocking and restricting consumption of food and water that may be contaminated, shortly followed by prompt monitoring and further urgent protective actions after a release. These actions will greatly reduce the off-site consequences. However, if evacuation cannot be implemented promptly, sheltering is also a possible countermeasure, but should be used with caution, depending on the nature of the emergency and the construction of buildings.

− Sheltering, if instituted, can only be a temporary measure;

− the protective action strategy to be implemented in the event of an emergency must be decided in advance after consideration of the site and facility characteristics, and insights on the effectiveness of various protective actions. For threat category I facilities, such as large nuclear reactors, or facilities with large amounts of spent fuel, an effective response strategy for an emergency involving damage to the core or fuel in the spent fuel pool would include:

- taking precautionary protective action nearby (3–5 km)[18], immediately upon detection of conditions within the facility that are likely leading to core or spent fuel damage, without waiting for dose projections (too slow and uncertain);
- promptly (within hours) conducting monitoring and initiate appropriate urgent protective action (e.g. evacuation) for the area within about 30 km[19] of a large reactor;
- promptly stopping consumption of local produce[20], milk from animals grazing on contaminated pasture or rainwater up to a distance of 300 km[21] until sampled and analysed;
- within days, conducting monitoring of ground deposition and initiate early protective actions (e.g. relocation) for the area within about 250–300 km;

− provision for promptly (within an hour of the predefined criteria being exceeded) making decisions concerning precautionary and urgent protective actions and subsequently notifying the public, is essential to reducing the probability of radiation health effects among the public in the event of a severe emergency;

− although the focus during an emergency will be on the actions to be taken to mitigate the consequences, criteria are also necessary for determining when protective actions can be lifted. People who have been evacuated will naturally wish to return to their homes and re-establish their normal activities. Thus, if precautionary countermeasures have been used, action will be necessary to assess the affected areas against the pre-established criteria so that they can be progressively lifted.

The objective of optimisation of protection is a progressive reduction in exposure to levels towards the lower end of the band, or below if possible. ICRP reiterates that the process for selecting the reference level should result from a careful balance of many inter-related factors, including the sustainability of social life and economic activities, as well as the quality of the environment, and should appropriately reflect the views of all relevant stakeholders.

Depending on the accident scenario, this could take several years, or even decades, because exposure of people living and working in contaminated areas largely depends on their habits and living conditions, which cannot be strictly controlled. It is therefore not possible to guarantee that all individual doses will be kept below the reference level in the long term. Selection of the reference level to manage the long-term phase is a complex decision that should be informed by societal and ethical value judgements. Due to this complexity, ICRP recommends that stakeholders who will be confronted with the situation should be involved as much as possible when selecting the value of the reference level.

[18] Area called the Precautionary Action Zone (PAZ).

[19] Area called the Urgent Protective Action Planning Zone (UPZ).

[20] Local produce is food that is grown in open spaces that may be directly contaminated by the release and that is consumed within weeks (e.g. leafy vegetables).

[21] Area called the food restriction planning radius.

PROTECTING EMERGENCY WORKERS AND HELPERS IN A NUCLEAR OR RADIOLOGICAL EMERGENCY

Concept of emergency worker. Concept of helpers

GSR Part 7 and GSR Part 3 define an emergency worker as «A person having specified duties as a worker in response to an emergency». Thus, any person engaged as a worker in response to a nuclear or radiological emergency at any time between the onset of the emergency and its termination is referred to as an «emergency worker» in the IAEA safety standards.

Emergency workers may include:

- Relevant employees of operating organizations (those employed directly by the operating organization and those engaged indirectly through a contractor) engaged in an emergency response on the site, including in the activities aimed at enabling the termination of the emergency;
- Relevant personnel from other response organizations and services, such as response managers, rescuers, firefighters, drivers and crews of evacuation vehicles, medical personnel, law enforcement personnel, members of monitoring teams, members of decontamination teams, and workers engaged in various activities on the site and off the site, including the restoration of essential infrastructure and the management of waste generated in the emergency;
- Relevant personnel engaged in providing support and care to the affected population (e.g. in reception centres).

Paragraph 5.49 of GSR Part 7 requires that emergency workers be, to the extent practicable, designated in advance, and para. 5.50 of GSR Part 7 requires that arrangements be made to register and integrate into operations those emergency workers who were not designated as such in advance of the emergency. Emergency workers designated in advance are required to be assessed for their fitness for the intended duties before their engagement in an emergency response and on a regular basis thereafter.

GSR Part 7 defines a helper in an emergency as a «Member of the public who willingly and voluntarily helps in the response to a nuclear or radiological emergency» even though such helpers are aware that they can be exposed to radiation while doing so.

While the engagement of helpers in the urgent response phase of an emergency is less expected, helpers can be increasingly engaged as the emergency evolves, particularly in the transition phase. Helpers in an emergency are members of the public and thus do not have the status of workers (for an employer) as defined in GSR Part 3. However, once registered and integrated into the emergency response operations, helpers are required to be protected in accordance with Requirement 11 of GSR Part 7.

GSR Part 7, GSR Part 3, GSG-2 and IAEA Safety Standards Series No. GSG-7, Occupational Radiation Protection establish the safety requirements for, and provide further recommendations and guidance on, the protection of emergency workers.

GSR Part 7 establishes the safety requirements for the protection of helpers in an emergency. The guidance provided in this Safety Guide addresses the specifics of the protection of emergency workers and helpers in the transition phase and complements these standards.

Paragraph 5.101 of GSR Part 7 states that «Once the emergency is terminated, all workers undertaking relevant work shall be subject to the relevant requirements for occupational exposure in planned exposure situations» established in Section 3 of GSR Part 3. This requirement draws on past experience, showing that the long term aspects can be subject to detailed planning that will allow for workers undertaking relevant work to be protected in accordance with the requirements for occupational exposure in planned exposure situations.

GSG-7 provides further recommendations and guidance on occupational radiation protection in planned exposure situations and existing exposure situations.

Any decision to terminate a nuclear or radiological emergency and to move to a planned exposure situation or an existing exposure situation should consider the feasibility of compliance with the requirements for occupational exposure in planned exposure situations for all workers engaged in recovery operations (see Section 3 GSG-11).

Identification and designation

Emergency workers

Emergency workers that will be engaged in the transition phase should be identified, to the extent possible, and designated as emergency workers at the preparedness stage by all relevant organizations. The relevant organizations, in this context, include response organizations, as well as other organizations at the national, regional and local levels. These organizations might not necessarily be recognized as emergency response organizations, but during the transition phase they may gradually take over a role and assume responsibilities for long term recovery, when applicable.

Relevant organizations should use the process of designating emergency workers who will be engaged in the transition phase to:

- Inform emergency workers of their rights, duties and responsibilities with regard to occupational radiation protection;
- Recognize the organizations» responsibilities, commitments and duties as employers in occupational radiation protection, so that those responsibilities, commitments and duties can be effectively discharged at the preparedness stage and in the transition phase.

The relevant organizations that may take over a role and assume responsibilities in the transition phase might not have the necessary expertise and capabilities to provide for radiation protection of their employees (i.e. emergency workers). Examples of such organizations include organizations carrying out the restoration of infrastructure or dealing with conventional waste within an affected area. Thus, such organizations may need to call on a relevant institution to provide such services and should make the necessary arrangements.

Irrespective of the arrangements referred to in para. 4.111 GSG-11, the responsibilities, commitments and duties in occupational radiation protection should remain with the relevant organization and cannot be transferred to the institution providing the services.

Helpers

Paragraph 5.50 of GSR Part 7 requires that the response organization(s) responsible for the registration and integration of helpers into the overall response in an emergency be designated at the preparedness stage. The designated response organization should be assigned the same responsibilities, commitments and duties in occupational radiation protection for helpers as for emergency workers.

As part of the emergency arrangements, such designated response organizations should determine:

- What type of work helpers are permitted to be engaged in during the transition phase and the type of training the helpers will need to safely and effectively carry out this work;
- A mechanism for the helpers» engagement (e.g. where and how volunteers from the public may express their interest and willingness to help, how the willingness to help will be documented, what information and instructions the helpers will be provided with, and which organization(s) or tasks they will be assigned to);
- The process for informing helpers about and training them in their rights, duties and responsibilities.

Radiation protection of emergency workers

The government shall ensure that arrangements are in place to protect emergency workers and to protect helpers in a nuclear or radiological emergency.

Arrangements shall be made to ensure that emergency workers are, to the extent practicable, designated in advance and are fit for the intended duty. These arrangements shall include health surveillance for emergency workers for the purpose of assessing their initial fitness and continuing fitness for their intended duties (see also GSR Part 3).

Arrangements shall be made to register and to integrate into operations in an emergency response those emergency workers who were not designated as such in advance of a nuclear or radiological emergency and helpers in an emergency. This shall include designation of the response organization(s) responsible for ensuring protection of emergency workers and protection of helpers in an emergency.

The operating organization and response organizations shall determine the anticipated hazardous conditions, both on the site and off the site, in which emergency workers might have to perform response functions in a nuclear or radiological emergency in accordance with the hazard assessment and the protection strategy.

The operating organization and response organizations shall ensure that arrangements are in place for the protection of emergency workers and protection of helpers in an emergency for the range of anticipated hazardous conditions in which they might have to perform response functions. These arrangements, as a minimum, shall include:

- Training those emergency workers designated as such in advance;
- Providing emergency workers not designated in advance and helpers in an emergency immediately before the conduct of their specified duties with instructions on how to perform the duties under emergency conditions («just in time» training);
- Managing, controlling and recording the doses received;
- Provision of appropriate specialized protective equipment and monitoring equipment;
- Provision of iodine thyroid blocking, as appropriate, if exposure due to radioactive iodine is possible;
- Obtaining informed consent to perform specified duties, when appropriate;
- Medical examination, longer term medical actions and psychological counselling, as appropriate.

The operating organization and response organizations shall ensure that all practicable means are used to minimize exposures of emergency workers and helpers in an emergency in the response to a nuclear or radiological emergency (para. I.2 of Appendix I GSR-7), and to optimize their protection.

In a nuclear or radiological emergency, the relevant requirements for occupational exposure in planned exposure situations established in GSR Part 3 shall be applied, on the basis of a graded approach, for emergency workers, except as required in para. 5.55 GSR-7.

The operating organization and response organizations shall ensure that no emergency worker is subject to an exposure in an emergency that could give rise to an effective dose in excess of 50 mSv other than:

- For the purposes of saving human life or preventing serious injury;
- When taking actions to prevent severe deterministic effects or actions to prevent the development of catastrophic conditions that could significantly affect people and the environment;
- When taking actions to avert a large collective dose.

For the exceptional circumstances below (para. 5.55 GSR-7), national guidance values shall be established for restricting the exposures of emergency workers, in accordance with Appendix I GSR-7.

The operating organization and response organizations shall ensure that emergency workers who undertake emergency response actions in which doses received might exceed an effective dose of 50 mSv do so voluntarily; that they have been clearly and comprehensively informed in advance of associated health risks as well as of available protective measures; and that they are, to the extent possible, trained in the actions that they might be required to take. Emergency workers not designated as such in advance shall not be the first emergency workers chosen for taking actions that could result in their doses exceeding the guidance values of dose for lifesaving actions, as given in Appendix I GSR-7. Helpers in an emergency shall not be allowed to take actions that could result in their receiving doses in excess of an effective dose of 50 mSv.

Arrangements shall be made to assess as soon as practicable the individual doses received in a response to a nuclear or radiological emergency by emergency workers and helpers in an emergency and, as appropriate, to restrict further exposures in the response to the emergency (see Appendix I GSR-7).

Emergency workers and helpers in an emergency shall be given appropriate medical attention for doses received in a response to a nuclear or radiological emergency (see Appendix II GSR-7) or at their request.

Emergency workers who receive doses in a response to a nuclear or radiological emergency shall normally not be precluded from incurring further occupational exposure. However, qualified medical advice shall be obtained before any further occupational exposure occurs if an emergency worker has received an effective dose exceeding 200 mSv, or at the request of the emergency worker.

Information on the doses received in the response to a nuclear or radiological emergency and information on any consequent health risks shall be communicated, as soon as practicable, to emergency workers and to helpers in an emergency.

Specific considerations for the transition phase

For an emergency involving significant long-lasting contamination of the environment that would require transition to an existing exposure situation, the protection of emergency workers and helpers in the transition phase will be challenged by:

- Large variations in the radiological conditions expected within the affected area in an emergency exposure situation, warranting the simultaneous application of different measures for the protection of emergency workers and helpers;
- Severe radiological conditions having been present at the site for a longer period and, thus, challenging the on-site response efforts;
- Different exposure situations existing simultaneously in different areas, warranting workers undertaking the same work to be subject to different dose restrictions;
- Large numbers of emergency workers involved from different organizations and services with diverse backgrounds, knowledge and expertise, some of whom might not have been identified and designated as emergency workers in advance of the emergency;
- Numerous members of the public volunteering to help.

The arrangements to protect emergency workers and helpers should take into account the need to implement simultaneously different schemes for the protection of emergency workers and helpers. However, a consistent approach should be applied for the protection of emergency workers and helpers, to the extent possible, with account taken of the requirements established and the guidance provided for this purpose in GSR Part 7, GSR Part 3, GSG-2 and GSG-7.

The application of different measures and dose restrictions to protect emergency workers and helpers in the transition phase could be a source of confusion among all concerned parties. Thus, any inconsistency in dose restrictions and measures to be applied for the protection of emergency workers and helpers, and the reason for this inconsistency, should be clearly communicated to all concerned parties.

Justification and optimization

The detriment associated with doses received during the implementation of the protection strategy by emergency workers and helpers should be taken into account when justifying the protection strategy and the specific protective actions within the strategy. This consideration should be undertaken at the preparedness stage, as well as in the transition phase, when justifying and optimizing the protection strategy to meet the actual circumstances.

At the preparedness stage, the process of optimization should be applied to the protection of emergency workers and helpers and should be driven by pre-set dose restrictions (see paras 4.120–4.129 GSG-11). When implementing the protection strategy in the transition phase, the optimization process should be applied for the protection of emergency workers and helpers in the same way as for workers in planned exposure situations.

Dose restrictions

Paragraphs 5.54 and 5.55 of GSR Part 7 stipulate that the relevant requirements for occupational exposure in planned exposure situations established in GSR Part 3 are required to be applied, on the basis of a graded approach, for emergency workers, except if their tasks involve:

a) actions to save human life or prevent serious injury;

b) actions to prevent severe deterministic effects or prevent the development of catastrophic conditions that could significantly affect people and the environment; or

c) actions to avert a large collective dose.

For such tasks, national guidance values are required to be established for restricting the exposures of emergency workers, with account taken of the guidance values given in appendix I to GSR Part 7. Actions to save lives, prevent severe deterministic effects or avert the development of catastrophic conditions that could significantly affect people and the environment are typical during the urgent response phase of a nuclear or radiological emergency. Although the implementation of these actions should be preplanned, it is expected that the actions would be driven by the prevailing conditions as the emergency evolves. Such actions would likely be carried out early in the emergency response when there is a scarcity of information about the radiological situation where the action is to be performed. Because of the urgency associated with implementing these actions and their importance, detailed planning of the work of emergency workers might not be possible; thus, exposures exceeding the dose limits for occupational radiation protection in planned exposure situations are justified to ensure the net benefit of the overall response efforts.

Actions to avert a large collective dose may extend through the early response phase and into the transition phase of an emergency because of the range of activities that are warranted to allow the timely resumption of social and economic activity. During the transition phase, knowledge and understanding of the situation where the work needs to be carried out increases, and there is no need to take urgent decisions on the deployment of workers. Thus, any work in the transition phase should be undertaken only after detailed planning. As a result, the protection of emergency workers in the transition phase should be applied stringently, in accordance with the requirements for occupational radiation protection for planned exposure situations, including the application of dose limits for occupational exposure in line with GSR Part 7 and GSR Part 3.

Paragraph 5.57 of GSR Part 7 limits the exposure of helpers in an emergency to an effective dose of 50 mSv for the full duration of the emergency work.

The protection and safety of emergency workers and helpers in the transition phase should be optimized, with account taken of the characteristics and necessity of the work to be carried out. The dose restrictions described in paras 4.120–4.123 GSG-11 are summarized in Table 15.

Table 15

Dose restrictions for emergency workers and helpers in the transition phase

<table>
<tr><th rowspan="2">Task</th><th colspan="3">Guidance value *</th></tr>
<tr><th>$H_p(10)$ **</th><th>E ***</th><th>AD_T +</th></tr>
<tr><td colspan="4">Emergency workers</td></tr>
<tr><td>Actions to avert a large collective dose, such as:
— Actions to keep the affected facility or source stable
— Monitoring (environmental, source, individual)</td><td><100 mSv</td><td><100 mSv</td><td><1/10 AD_T, Table II.1 ++</td></tr>
<tr><td>Other activities, such as:
— Remedial actions, including decontamination on the site and off the site
— Repair of the affected facility and restoration of the relevant essential infrastructure
— Management of radioactive waste and conventional waste
— Environmental, source and individual monitoring
— Medical management of contaminated patients
— Implementation of corrective actions</td><td colspan="3">Dose limits for occupational exposure in planned exposure situations established in schedule III of GSR Part 3</td></tr>
<tr><td colspan="4">Helpers</td></tr>
<tr><td rowspan="2">Specified activities in the national arrangements, such as:
— Restoring essential infrastructure (e.g. roads, public transportation networks)
— Management of conventional waste</td><td colspan="3">E ***</td></tr>
<tr><td colspan="3">≤50 mSv</td></tr>
</table>

* These values apply to:
a) The dose from external exposure to strongly penetrating radiation for Hp(10). Doses from external exposure to weakly penetrating radiation and from intake or skin contamination need to be prevented by all possible means. If prevention is not feasible, the effective dose and the RBE (relative biological effectiveness) weighted absorbed dose to a tissue or organ have to be limited to minimize the health risk to the individual in line with the risk associated with the guidance values given here.
b) The total effective dose (E) and the RBE weighted absorbed dose to a tissue or organ (ADT) via all exposure pathways (i.e. dose from external exposure and committed dose from intakes), which are to be estimated as early as possible to enable any further exposure to be restricted as appropriate.
** Personal dose equivalent Hp(d), where d = 10 mm.
*** Effective dose.
+ RBE weighted absorbed dose to a tissue or organ.
++ Value of RBE weighted absorbed dose to a tissue or organ given in table II.1 of appendix II to GSR Part 7.

Dose restrictions for female emergency workers who are or who might be pregnant

GSR Part 7, GSG-2 and GSG-7 do not limit the involvement of female emergency workers in an emergency response. However, these standards establish requirements and provide guidance for protecting the fetus in case of a possible pregnancy of a female emergency worker.

In the circumstance of para. 4.125, GSR Part 7 states that female workers “who are aware that they are pregnant or who might be pregnant” are required to be informed of the risk of severe deterministic effects to a fetus arising from an exposure of greater than 100 mSv equivalent dose to the fetus. Therefore, any pregnant female worker is required to be excluded from taking actions to avert a large collective dose if these actions could result in an equivalent dose to the embryo or fetus exceeding 50 mSv for the full period of in utero development. Situations in which a worker may receive doses at these levels are primarily expected early in the emergency response (i.e. during the urgent response phase).

For those activities to be carried out in accordance with the requirements established in Section 3 of GSR Part 3 for occupational radiation protection during a planned exposure situation, the working conditions for female workers who are pregnant or suspect that they are pregnant or who are breast-feeding need to afford the same broad level of protection to the embryo or fetus or the breastfed infant as that required for members of the public in a planned exposure situation.

To ensure adequate protection of the fetus, female emergency workers who are aware that they are, or who might be, pregnant should notify their employers before undertaking relevant work. After being notified, the employer has the responsibility to inform the emergency worker of the associated health risks to the fetus and to provide adequate working conditions and protective measures to ensure compliance with the dose restrictions described in paras 4.126 and 4.127 GSG-11.

In order to protect the embryo or fetus, all relevant organizations should make adequate arrangements to:

- Encourage female workers to notify their employer of an actual or suspected pregnancy;
- Inform female workers who are or who might be pregnant of the associated health risks before they undertake the assigned work;
- Assess and monitor the conditions in which female emergency workers who are or who might be pregnant may need to work;
- Ensure that adequate protective equipment is provided to female emergency workers who are or who might be pregnant, and ensure that they are trained in its use;
- Assess the equivalent dose to the embryo or fetus after the emergency work as a basis for determining whether the further involvement of the female emergency worker needs to be restricted and whether medical consultation is warranted.

Dose management

The adequate management of doses to emergency workers and helpers warrants the establishment of a comprehensive system for monitoring and controlling doses, including the use of individual dosimeters or other appropriate methods. GSG-7 provides guidance on monitoring for the assessment of internal and external exposures relevant to occupational radiation protection.

To ensure that doses to emergency workers and helpers are adequately managed in the transition phase, all relevant organizations should make arrangements to:

- Register the emergency workers and helpers engaged in the emergency response;
- Continuously monitor hazardous conditions in which emergency workers and helpers are to perform their duties;
- Comprehensively plan the expected work in an emergency response, while accounting for the hazardous conditions present and the time needed to complete the work;
- Assess the total effective dose and the relative biological effectiveness (RBE) weighted absorbed doses to a tissue or organ for emergency workers and helpers via all exposure pathways, as appropriate;
- Record the doses received;
- Communicate to emergency workers and helpers in plain and understandable language the doses they receive, and place the associated health hazards in perspective.

Response organizations and other relevant organizations should optimize the protection and safety of emergency workers and helpers in recognition of the limited information available at the preparedness stage, taking into account the anticipated hazardous conditions and expected duties in an emergency response. In this context, these organizations should identify:

- The needs for training and for personal protective and monitoring equipment;
- The need to implement iodine thyroid blocking and/or provide adequate personal protective equipment to emergency workers against the inhalation of radioactive iodine and other radionuclides in cases of prolonged working activities in the transition phase;
- Tasks during which emergency workers may be subject to exposures exceeding occupational dose limits;
- To whom employers need to provide comprehensive information on the risk involved as a basis for obtaining informed consent;
- The need for regular health surveillance to assess the initial and continued fitness of emergency workers for their intended duties.

The implementation of the arrangements set out in paras 4.131 and 4.132 GSG-11 for emergency workers not designated in advance and for helpers may encounter the following challenges:

- Emergency workers not designated in advance and helpers might not have had any recognized rights and duties in relation to occupational radiation protection before their involvement and thus might not have received any training in radiation protection.
- The employers of emergency workers not designated in advance might not have the capacity to discharge their responsibilities, duties and commitments in the occupational radiation protection of these workers.
- Helpers will not have an employer who would provide for their protection.
- No assessment of the health condition (i.e. fitness for duty) of emergency workers not designated in advance and of helpers may be possible before they undertake emergency work.

In the circumstances described in para. 4.133 GSG-11, designated response organization(s) are required by para. 5.50 of GSR Part 7 to register and to integrate into emergency response operations those emergency workers not designated in advance and helpers and, thus, provide for their protection. Such designated response organization(s) should be given the responsibility to implement, as appropriate, the arrangements set out in paras 4.131 and 4.132 GSG-11 for emergency workers not designated in advance and for helpers.

Such dedicated response organizations should also be responsible for the provision of «just in time» training to emergency workers not designated in advance and to helpers before they carry out their specified duties. Such training should include:

- Instructions on the duties assigned and how to carry out those duties under the assessed conditions;
- Information on the health risks associated with performing these duties;
- The protective measures available and how they should be implemented effectively.

These arrangements should also provide the organization with an opportunity to obtain informed consent from emergency workers assigned to perform the tasks listed in Table 15, for which the dose limits for occupational radiation protection in a planned exposure situation might be exceeded.

Provision of medical support

GSR Part 7 provides a basis for a common approach in providing medical support to emergency workers and helpers. This approach includes a generic criterion, in terms of received dose, consistent with the criterion for members of the public (an effective dose of 100 mSv in a month) at which longer term medical actions need to be taken. Such medical actions may include, as necessary, health screening, longer term medical follow-up and counselling aimed at detecting radiation induced health effects early and treating them effectively.

In the transition phase, it is not expected that emergency workers and helpers will receive doses exceeding 100 mSv effective dose in a month or approaching the thresholds for severe deterministic effects. If doses of this magnitude are received accidentally, the circumstances that have led to this should be investigated and the emergency worker or helper should be provided with adequate medical treatment in accordance with the requirements of GSR Part 7.

Irrespective of the doses received, emergency workers and helpers need to have the right to psychological counselling and continuous medical care during the emergency response, including in the transition phase. Thus, the emergency arrangements should be such that both psychological counselling and continuous medical care can be provided, and the organizations and facilities responsible for providing these services should be identified.

Consideration for other workers

In the transition phase, other categories of workers may carry out work within an affected area. Examples include teachers and the medical staff of hospitals working in an affected area to prepare that area for the return of the population.

The workers referred to in para. 4.140 GSG-11 should be protected by their employers at the same level as members of the public within the area, and thus those workers should be subject to the reference levels agreed to be applied for members of the public to allow for the transition to take place (see paras 4.52–4.61 GSG-11). The application of the reference level for the residual dose for such workers should take into account that some of these workers may also reside in the affected area (and thus spend their entire time within the affected area as workers and as members of the public).

As noted in para. 3.8 GSG-11, among the prerequisites to be met before the termination of the emergency are the detailed characterization of the radiological situation, the identification of exposure pathways and the assessment of the doses to the affected populations. The characterization of the exposure situation should be performed in the transition phase to support, as appropriate:

- Adjusting the implementation of the protection strategy on the basis of actual circumstances, including the adaptation or lifting of specific protective actions;
- Identifying measures necessary for protecting emergency workers and helpers;
- Identifying those individuals to be registered and needing longer term medical follow-up;
- Decision making on the termination of the emergency;
- Planning for long term recovery within the new exposure situation.

An emergency resulting in long term exposures due to residual radioactive material in the environment warrants continued monitoring in the longer term within an existing exposure situation. In accordance with the guidance provided in this Safety Guide, the development of a long term monitoring strategy should be initiated in the transition phase to enable the prerequisite in para. 3.20(h) GSG-11 to be met.

IAEA Safety Standards Series No. RS-G-1.8, Environmental and Source Monitoring for Purposes of Radiation Protection, provides recommendations and guidance on environmental and source monitoring for the purposes of radiation protection in various circumstances, including in emergency exposure situations, and outlines some considerations relating to dose assessment and the interpretation of monitoring results.

Preparedness stage

To characterize the exposure situation in detail, monitoring (environmental, source and individual monitoring, as appropriate) should be carried out. A monitoring strategy should be developed at the preparedness stage on the basis of the hazards identified and the potential consequences assessed at the preparedness stage, with account taken of the available resources. The monitoring strategy should stipulate priorities for the different phases of the emergency in accordance with the protection strategy.

The monitoring strategy should provide for assessing doses to the affected population and should focus primarily on the following exposure pathways:

- External exposure from radionuclides deposited on the ground;
- Internal exposure due to ingestion of radionuclides incorporated in food, milk and drinking water;
- Internal exposure due to inhalation of resuspended radionuclides.

As part of the monitoring strategy, the available resources for monitoring should be identified and should include, but not be limited to:

- The organizations, expert bodies, local and national laboratories, private institutes, universities and research centres responsible for implementing the monitoring strategy;

- The availability of human resources and technical capabilities (including monitoring equipment and dose assessment tools) in each of these entities for implementing the monitoring strategy;
- Mechanisms for ensuring the comparability and consistency of measurements and for their interpretation, including training, quality management and intercomparison exercises;
- An organization designated as responsible for the validation, recording and retention of monitoring results and assessments;
- A mechanism for incorporating monitoring results and assessments into the decision making processes.

Monitoring data are an important basis for decision making in all phases of the emergency. The monitoring strategy may be supported by decision aiding tools and models in assessing and adjusting the priorities for monitoring in order to allow for the effective and efficient use of available (but usually limited) resources and capabilities. However, monitoring should ultimately be conducted in all geographical areas and not just in those areas indicated by modelling tools. The objective of using such tools and their limitations should be clearly communicated to all concerned parties and documented in the monitoring strategy.

The uncertainties associated with the results of the monitoring will, in turn, contribute to the overall uncertainty associated with the estimated impact of an emergency; consequently, these uncertainties might affect the quality of the decision making process. These uncertainties may be of technical origin (variability of procedures for sampling, processing and measurement; spatial and temporal variability of the measured quantity; variability of calibration procedures) due to the non-representativeness of samples and/or measurements and/or human error (e.g. from a lack of training). Therefore, appropriate quality assurance requirements should be agreed on at the preparedness stage to reduce such technical uncertainties as much as possible, and these quality assurance requirements should be observed by all parties providing measurements during the emergency response. To reduce human errors, the individuals involved in radiation monitoring should be periodically trained and human interference in monitoring procedures should be minimized when appropriate.

Transition phase

In an emergency involving a radioactive release to the environment, depending on the severity of the emergency, characterization of the radiological conditions may involve atmospheric modelling, wide area environmental monitoring and direct measurements, or a combination of these (see RS-G-1.8). In the transition phase, reliable data from monitoring should be obtained by direct measurements to accurately characterize the nature of radioactivity in the environment.

The radionuclide composition of the release has a major impact on the doses that will be received and on the contribution of each exposure pathway. Therefore, the radionuclide composition of the release or of any contamination should be identified as early as possible.

Evaluation of the external dose, dose rate and deposition measurements should be carried out. Therefore, detailed radionuclide specific deposition maps and external gamma dose rate maps should be established as soon as possible and should be periodically updated, with account taken of the fact that the deposition of the radionuclides will be subjected to redistribution due to weathering effects (such as resuspension) or natural radioactive decay processes over time.

Particular attention should be given to the possibility of heterogeneity in the deposition patterns due to the variation in the spectrum of released radionuclides and the weather conditions prevailing during the emergency response phase. Meteorological analyses and forecasts, especially of rainfall, wind and atmospheric stability data, as well as atmospheric transport modelling, may help to identify areas of potentially higher deposition.

Maps of deposition patterns and of external gamma dose rate should be prepared in the transition phase. Such maps should be shared with interested parties, and the maps should be accompanied by plain language explanations of the associated health hazards and the need for protective actions.

Exposure due to the ingestion of contaminated food, milk and drinking water may result from occasional or continual intakes. A comprehensive sampling and monitoring programme should be carried out to allow for continual analysis and assessment of the levels of radionuclides in food, milk and drinking water; of the doses received from the ingestion pathway; and of the need for any adaptation of the restrictions imposed on food, milk and drinking water. The monitoring programme should take into account local diets and food preferences as well as food production patterns. The monitoring results should be made publicly available to provide reassurance of the safety of the food, milk and drinking water intended for consumption.

In the transition phase, internal exposure due to the inhalation of resuspended material can be expected. While the contribution of this pathway to the total effective dose is usually small, particular circumstances (e.g. carrying out activities in an arid, windy environment or in a dusty environment) may lead to this exposure pathway contributing significantly to total doses. The potential for internal exposure due to inhalation should be taken into consideration, and monitoring for resuspended particles should be included in the monitoring programme as appropriate.

Doses should be reassessed by incorporating the monitoring results into the dose assessment tools and models selected as part of the monitoring strategy developed at the preparedness stage. Estimations should be carried out as realistically as possible and should focus on the doses to the representative person or groups, with account taken of realistic habits; the actual patterns of contamination; and the food, milk and drinking water that are used by people in the contaminated areas. Assessed doses (projected, received or residual doses) should be compared with the generic criteria and reference levels pre-set in the protection strategy or with the dose restrictions applicable to emergency workers and helpers.

Medical follow-up and provision of mental health and psychosocial support

This subsection describes the emergency arrangements to be made to implement longer term medical follow-up and to provide mental health and psychosocial support following a nuclear or radiological emergency, in light of its public perception and the impact on the termination of the emergency. Generic procedures for medical response in a nuclear or radiological emergency, including for longer term medical follow-up and psychological counselling, are provided in EPR-Medical 2005. Guidelines on mental health and psychosocial support in emergencies are provided in:

- Humanitarian Intervention Guide (mhGAP-HIG): Clinical Management of Mental, Neurological and Substance Use Conditions in Humanitarian Emergencies, WHO, Geneva (2015);
- Psychological First Aid: Guide for Field Workers, WHO, Geneva (2011);
- Guidelines on Mental Health and Psychosocial Support in Emergency Settings, IASC, Geneva (2007).

GSR Part 7 states that:

«5.67. Arrangements shall be made to identify individuals with possible contamination and individuals who have possibly been sufficiently exposed for radiation induced health effects to result, and to provide them with appropriate medical attention, including longer term medical follow-up.

5.68. Arrangements shall be made for the identification of individuals who are in those population groups that are at risk of sustaining increases in the incidence of cancers as a result of radiation exposure in a nuclear or radiological emergency. Arrangements shall be made to take longer term medical actions to detect radiation induced health effects among such population groups in time to allow for their effective treatment».

This arrangements are required to include (see Requirement 12 of GSR Part 7):

- Guidelines for effective diagnosis and treatment;
- Designation of medical personnel trained in clinical management of radiation injuries;

- Designation of institutions for evaluating radiation exposure (external and internal), for providing specialized medical treatment and for longer term medical actions;
- Criteria for identifying the individuals referred to in para. 4.159 GSG-11 and for their registration (see appendix II to GSR Part 7 and GSG-2).

Before deciding on the termination of the emergency, the following prerequisites should be met with regard to longer term medical follow-up and to mental health and psychosocial support:

- A registry has been established of those individuals who have been identified, by the time the emergency is to be terminated, as requiring longer term medical follow-up, on the basis of criteria established in table II.1 and table II.2 of GSR Part 7 (see also GSG-2 for further details).
- A programme for longer term medical follow-up for registered individuals has been established.
- For the transition to an existing exposure situation, a strategy for mental health and psychosocial support of the affected population has been developed.

The medical follow-up referred to in para. 4.161 GSG-11 should have the following objectives:

- To provide for the long term medical care of individuals who have suffered deterministic effects and of individuals incurring doses that exceed the threshold dose for deterministic effects;
- To provide for the early detection and diagnosis of stochastic effects (e.g. thyroid cancer) among the exposed population in order to allow for effective treatment.

The mental health and psychosocial support referred to in para. 4.161 GSG-11 should have the objective of reducing adverse psychological and societal consequences for the wider affected population, such as evacuees and people relocated after a decision has been made to lift evacuation and/or relocation, even if radiation induced health effects are not expected to be observed among that population.

The objectives of medical follow-up and mental health and psychosocial support should be clearly explained to those involved to ensure that the expectations of all relevant parties are appropriate.

Coordinating mechanism

The mechanism for coordinating the necessary arrangements to implement the medical follow-up and to provide mental health and psychosocial support following a nuclear or radiological emergency should be identified at the preparedness stage. The coordinating mechanism may involve an existing organization that is designated to act as a coordinating authority in this area or a newly established body consisting of representatives from authorities in public health, radiation protection, emergency management and epidemiology, and other relevant authorities.

The coordinating mechanism established in accordance with para. 4.165 should coordinate arrangements to be put in place at the preparedness stage by the relevant organizations with responsibilities for medical follow-up and for the provision of mental health and psychosocial support. The coordinating mechanism should coordinate the actions of the relevant organizations during an emergency response within a unified emergency response organization.

The responsible authority within the coordinating mechanism should, at the preparedness stage, establish criteria for identifying and registering those individuals requiring longer term medical follow-up and mental health and psychosocial support. These criteria should take into account the relevant criteria set out in GSR Part 7 and GSG-2] and should be subject to agreement by all relevant authorities.

Registering individuals for longer term medical follow-up

If a nuclear or radiological emergency occurs, registration of those individuals who may require longer term medical follow-up on the basis of predetermined criteria should be an important response action in the protection strategy. National response organization(s) should be designated to maintain the registry.

The data and information to be gathered in the registry should be determined at the preparedness stage and may include basic contact details (e.g. name, date of birth, gender, address, telephone number); information on the circumstances under which exposures occurred during the emergency (e.g. location at the time of the event, duration of exposure, activities carried out); and any relevant medical history (e.g. previous illnesses, co-morbidities, family history, workplace history, habits).

An initial registration should be carried out by employers or first responders that would allow for completion of the registry later on. Arrangements should be made for transferring information to the organization designated for the maintenance of the registry.

Registered individuals should be provided with the necessary information, including the reason for their selection for longer term medical follow-up; the assessed doses and associated health risks; a contact point at the institution responsible for the medical follow-up; a record of the procedures and laboratory tests performed, if appropriate (e.g. radiological and clinical assessments, blood tests); a description of the symptoms that may eventually present and whom to consult in the case of the presentation of symptoms. Such individuals should also be given the opportunity to ask questions and should be offered psychological support.

The information on the doses received by patients, as well as their medical histories and associated records, should be handled in accordance with the usual conditions of doctor–patient confidentiality and should be securely stored in accordance with conditions established by the health authorities.

Medical follow-up

As part of the arrangements for the medical follow-up, the following should be considered:

- The initial duration of the medical follow-up;
- The management of the information and the reporting and sharing of results;
- The identification of medical specialists to be involved in the medical follow-up;
- The management of biological and non-biological samples;
- The management of mental health and psychosocial consequences;
- Ethical and cost–benefit aspects.

Arrangements for longer term medical follow-up should ensure that individuals are provided with access to information about the results of their medical evaluations and to adequate sources of information, such as health care providers.

Decisions on the medical follow-up of individuals in relation to deterministic effects should be made by medical specialists on the basis of established clinical criteria, with consideration of the assessed doses (see GSR Part 7 and GSR Part 3) and individual health risk assessment. Consideration should be given to including these individuals in screening and monitoring programmes for stochastic effects as well.

Screening and monitoring programmes for stochastic effects should be based on criteria that are supported by scientific evidence for observing an increase in the incidence of cancer among the exposed population (see GSR Part 7 and GSR Part 3). The inclusion of non-cancer health effects in the monitoring programme should be carefully considered. If limited resources are available, the most vulnerable population groups, such as children and pregnant women, should be prioritized for longer term medical follow-up.

Mental health and psychosocial support

Arrangements should be made to provide mental health and psychosocial support for people being evacuated, relocated or returning to live normally in the affected area and to support their well-being. In these arrangements, people»s lifestyles and people»s need for reassurance following a nuclear or radiological emergency should be taken into account. Such arrangements should facilitate two-way communication between the authorities and concerned parties.

As part of the arrangements set forth in para. 4.177 GSG-11, the establishment of a public support centre for affected populations should be considered. Local doctors, nurses, pharmacists, psychologists, respective experts from public universities and associations, and others who are in positions of trust and who have the respect of the community should be considered for participation in the work of the public support centres. Information that places the health hazards in perspective and training on effective approaches to risk communication, tailored to various population groups, should also be given to local doctors, nurses, pharmacists, psychologists and other health care specialists to enable them to provide advice to the public within the settings of their health care practices.

«Just in time training» for non-designated emergency workers

GSR Part 7 states that:

- «The operating organization and response organizations shall identify the knowledge, skills and abilities necessary to perform the functions [for emergency response]» (para. 6.28 of GSR Part 7).
- «The government shall ensure that personnel relevant for emergency response shall take part in regular training, drills and exercises to ensure that they are able to perform their assigned response functions effectively in a nuclear or radiological emergency» (Requirement 25 of GSR Part 7).
- «Exercise programmes shall be developed and implemented to ensure that all specified functions…for emergency response [and] all organizational interfaces…are tested at suitable intervals» (para. 6.30 of GSR Part 7).
- «The operating organization and response organizations shall make arrangements to review and evaluate responses in actual events and in exercises, in order to record the areas in which improvements are necessary and to ensure that the necessary improvements are made» (para 6.38 of GSR Part 7).

The knowledge, skills and abilities necessary to carry out activities in the transition phase may differ from and extend beyond the knowledge, skills and abilities necessary in the emergency response phase. Therefore, the selection of the requisite knowledge, skills and abilities for personnel who will be involved in the transition phase should consider the different aspects of the transition phase and should also be directed at those personnel who will actually be engaged.

The training programmes in emergency preparedness and response developed at different levels for the transition phase should consider the personnel who will participate in the training and retraining. These programmes should also consider the level of the training (e.g. its duration, frequency, type and format, and arrangements for performance review) warranted for different personnel carrying out different activities in the transition phase.

The exercise programmes developed and implemented to systematically test the overall adequacy and effectiveness of the emergency arrangements should include the objective of testing existing arrangements set up to facilitate the timely resumption of normal social and economic activity within an agreed time frame (e.g. within three to five years), including the participation of the relevant organizations. Small scale exercises (e.g. tabletop exercises) should also be designed and used frequently to test various aspects of the transition phase within an organization (e.g. coordination, information exchange, transfer of information and data, changes in authority and in discharge of responsibilities, decision making processes) at the facility, local, regional or national levels.

As part of the management system, training, drill and exercise programmes should be evaluated, and areas of improvement should be identified. The feedback from this evaluation should be used to review and, as necessary, revise the emergency arrangements for the transition phase.

Personal protective equipment

1) The equipment provided depends on the severity of the hazard, and could include the following:

2) Respiratory protection: self-contained breathing apparatus is most effective. Filter-canister masks provide a good protection against iodines and particulate but are not effective against tritium.

3) Protective clothing: protective clothing must be based on the type of hazard. For emergencies in threat categories I, II and III, the high skin doses which can be received from beta radiation should be taken into consideration. For example, there should be no exposed skin; for fire fighters, protective suits should be non-plastic (or of a material which melts on the skin); for personnel expected to perform hard work and/or get wet, suits should be waterproof.

4) Thyroid blocking agent (threat categories I and II): it should be issued to all emergency workers prior to potential radioiodine exposures.

5) Dosimeters: each worker should wear thermoluminescent dosimeters in order to providea record of the accumulated dose after the emergency. Each person on the team should carry a self-reading (e.g. electronic) dosimeter (up to 250 mSv).

6) Survey instruments: at least one person in each team should carry a very high dose rate metre (up to 10 Gy/h). Contamination survey instruments must be available to monitor emergency workers on their exit from contaminated areas. These could include: hand- and-foot monitors, portal monitors, portable portal monitors, contamination probes (pancake probes) and scintillator probes. Care must be taken to avoid contaminating the probes.

7) Clothing: spare clothing and disposal facilities (plastic bags) should be available at the control point to replace contaminated clothing, as required.

8) Communication equipment that is operational in the areas where personnel may travel.

TERMINATION OF A NUCLEAR OR RADIOLOGICAL EMERGENCY

Primary objective

In 2020, the International Commission on Radiological Protection (ICRP) issued Publication 146 titled «Radiological protection of people and the environment in the event of a large nuclear accident» (ICRP, 2020). This publication updates and supersedes Publications 109 and 111 (ICRP, 2009a,b) in light of experience of the accidents at Chernobyl and Fukushima nuclear power plants. The objective of radiological protection is to mitigate radiological consequences for people and the environment. The recommendations of Publication 146 acknowledge the key role of both radiological and non-radiological factors in managing the consequences of an accident. This article focuses mainly on the long-term phase, often called «post-accident recovery», including relevant general considerations.

Under Article 5(a)(ii) of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency, one function of the IAEA is to «collect and disseminate to States Parties and Member States information concerning: …methodologies, techniques and available results of research relating to response to nuclear accidents or radiological emergencies».

Requirement 18 of GSR Part 7 requires the government to ensure that arrangements are made **for «the termination of a nuclear or radiological emergency, with account taken of the need for the resumption of social and economic activity».** Most States have paid particular attention to ensuring adequate preparedness to respond effectively to a nuclear or radiological emergency in order to protect human life, health, property and the environment early in the response. However, less attention has been devoted, at the preparedness stage, to practical arrangements for dealing with the challenges associated with the termination of an emergency and the transition to the «new normality». Past experience has demonstrated the importance of being prepared to address these challenges. To assist Member States in addressing these challenges, GSG-11 provides guidance and recommendations on emergency arrangements for the termination of a nuclear or radiological emergency and the subsequent transition to either a planned exposure situation or an existing exposure situation to meet the relevant safety requirements established in GSR Part 7.

Adjustment of protective actions and other response actions and of other arrangements that are aimed at enabling the termination of an emergency shall be made by a formal process that includes consultation of interested parties.

Arrangements for communication with the public in a nuclear or radiological emergency (see Requirement 13 GSR Part 7) shall include arrangements for communication on the reasons for any adjustment of protective actions and other response actions and other arrangements aimed at enabling the termination of the emergency. This shall include providing the public with information on the need for any continuing protective actions following termination of the emergency and on any necessary modifications to their personal behaviour.

Arrangements shall be made, during this period, to closely monitor public opinion and the reaction in the news media in order to ensure that any concerns can be promptly addressed.

These arrangements shall ensure that any information provided to the public puts health hazards in perspective.

The termination of a nuclear or radiological emergency shall be based on a formal decision that is made public and shall include prior consultation with interested parties, as appropriate.

Both radiological consequences and non-radiological consequences shall be considered in deciding on the termination of an emergency as well as in the justification and optimization of further protection strategies as necessary.

The transition to an existing exposure situation or to a planned exposure situation shall be made in a coordinated and orderly manner, by making any necessary transfer of responsibilities and with the increased involvement of relevant authorities and interested parties.

The government shall ensure that, as part of its emergency preparedness, arrangements are in place for the termination of a nuclear or radiological emergency. The arrangements shall take into account that the termination of an emergency might be at different times in different geographical areas. The planning process shall include as appropriate:

a) The roles and functions of organizations;

b) Methods of transferring information;

c) Means for assessing radiological consequences and non-radiological consequences;

d) Conditions, criteria and objectives to be met for enabling the termination of a nuclear or radiological emergency (see Appendix II GSR Part 7);

e) A review of the hazard assessment and of the emergency arrangements;

f) Establishment of national guidelines for the termination of an emergency;

g) Arrangements for continued communication with the public, and for monitoring of public opinion and the reaction in the news media;

h) Arrangements for consultation of interested parties.

Once the emergency is terminated, all workers undertaking relevant work shall be subject to the relevant requirements for occupational exposure in planned exposure situations, and individual monitoring, environmental monitoring and health surveillance shall be conducted subject to the requirements for planned exposure situations or existing exposure situations, as appropriate.

The concept of the «transition phase» refers to the process and the time period during which there is a progression to the point at which an emergency can be terminated. During this period, the relevant prerequisites (Section 3 GSG-11) that should be fulfilled before the termination of the emergency can be declared are gradually addressed.

In this context it is generally assumed that the transition phase commences as early as possible once the source has been brought under control and the situation is stable; the transition phase ends when all the necessary prerequisites for terminating the emergency have been met.

A situation is considered stable when the source has been brought under control, no further significant accidental releases or exposures resulting from the event are expected and the future development of the situation is well understood.

The termination of a nuclear or radiological emergency marks the end of the emergency, and therefore the emergency exposure situation, and the beginning of either an existing exposure situation or a planned exposure situation.

The various phases of a nuclear or radiological emergency are distinguished on the basis of the different timescales in which specific protective actions and other response actions are to be undertaken in order to achieve the goals of emergency response (see para. 3.2 of GSR Part 7) and to fulfil the prerequisites that would allow the declaration of the end of the emergency. The transition phase may last from a day to a few weeks for a small scale emergency (e.g. a lost or stolen dangerous source) but could last months to a year for a large scale emergency (e.g. an emergency at a nuclear installation resulting in significant off-site contamination).

In GSG-11, the distinction between the various phases of a nuclear or radiological emergency is intended to support the planning efforts for each phase at the preparedness stage as well as to facilitate communication and a common understanding among those involved in the planning. These efforts depend on the characteristics of each phase, including the information available and the specific activities to be carried out.

The response to a nuclear or radiological emergency is a continuous effort; therefore, during the response it is not intended that a distinction be made between the various phases of the emergency (para. 2.13 GSG-11).

The period covering the management of an existing exposure situation and the long term recovery operations after the emergency has been declared to have ended is excluded from the scope of GSG-11 and is covered in IAEA Safety Standards Series No. WS-G-3.1, Remediation Process for Areas Affected by Past Activities and Accidents and IAEA Safety Standards Series No. GSG-8, Radiation Protection of the Public and the Environment (see Fig. 15).

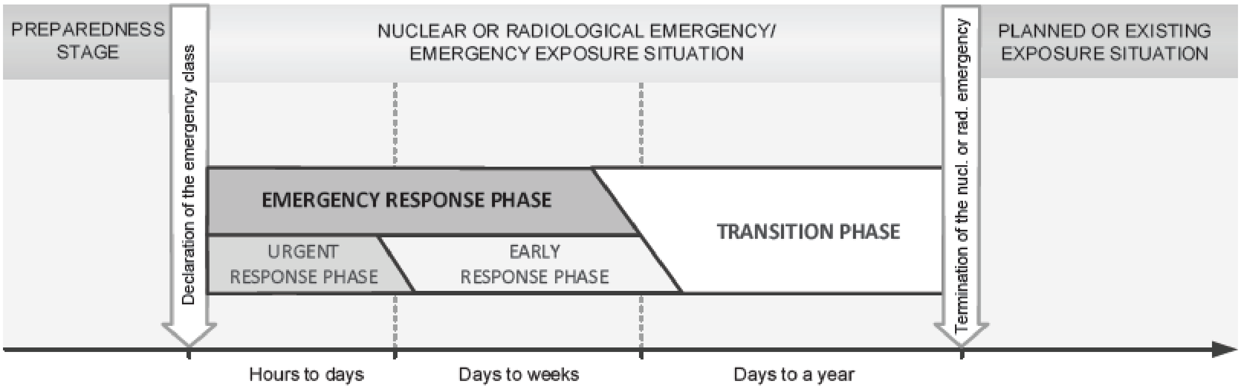

Fig. 15. Temporal sequence of the various phases and exposure situations for a nuclear or radiological emergency within a single geographical area or a single site.

While the distinction between various phases of a nuclear or radiological emergency may be helpful for planning purposes, it can be difficult to clearly define a line between the various phases of an emergency during the emergency response as the emergency response actions are implemented on a continuous basis (see Fig. 16). This lack of clear distinction is particularly true for the early response phase and the transition phase, when the activities that are carried out may support the implementation of specific actions and activities associated with both phases. For example, a monitoring strategy implemented during the early response phase may support both the decision making on early protective actions and the assessment of the radiological situation, which may in turn help to determine how protection strategies are to be further adapted.

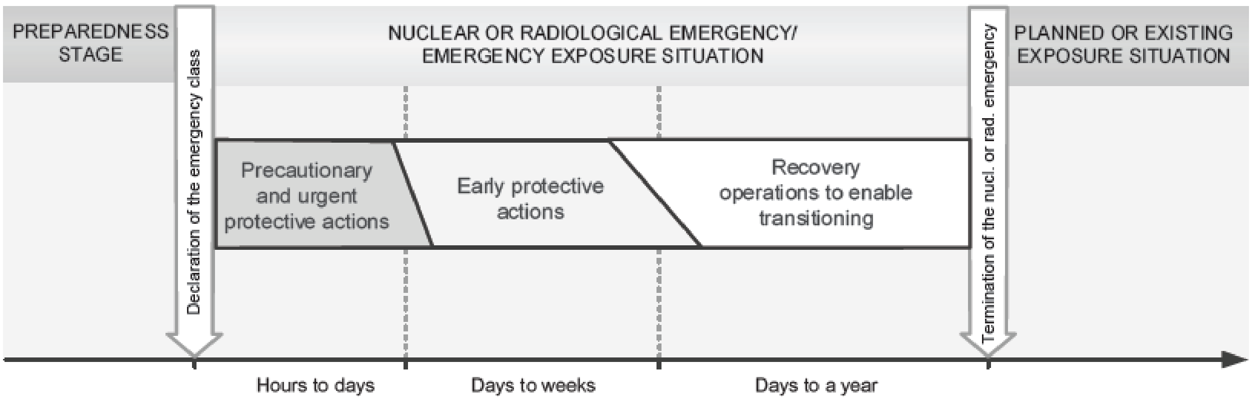

Fig. 16. Temporal sequence of various types of protective actions and recovery operations for a nuclear or radiological emergency within a single geographical area or a single site.

In a large scale emergency, the complexity of the radiological situation may vary greatly within an affected area and may be transient in nature. It is therefore likely that different phases and different exposure situations will coexist geographically and temporally. This coexistence challenges both the management of the situation and the communication with interested parties.

The transition from the emergency exposure situation will occur gradually in specific areas within the whole affected area. In this case, the transition phase will end when the final area that was in an emergency exposure situation has transitioned to an existing exposure situation. The transition of this final area to an existing exposure situation will also denote the overall termination of the emergency.

The emergency should be terminated if the relevant prerequisites set forth in this section and selected on the basis of a graded approach have been fulfilled; the decision to terminate the emergency should be a formal decision and should be made public.

The new exposure situation should then be managed as either a planned exposure situation or an existing exposure situation (see Fig. 1), as appropriate, in line with the national legal and regulatory framework as required in GSR Part 7, GSR Part 3 and IAEA Safety Standards Series No. GSR Part 1, Governmental, Legal and Regulatory Framework for Safety.

It should be recognized that:

a) The transition from the emergency exposure situation will likely take place at different geographical areas or at different parts of the site at different points in time. The situation in some geographical areas or some parts of the site might therefore continue to be managed as a nuclear or radiological emergency, while the situation in other areas might be managed as a planned exposure situation or an existing exposure situation, as appropriate.

b) Some of the prerequisites set out in this section are to be fulfilled by the operating organization in addition to responsible off-site response organizations. To a great extent, the transition from the emergency exposure situation in areas off the site will be subject to confirmation by the operating organization that the respective prerequisites16 have been fulfilled on the site.

The primary objective of the termination of the emergency is to facilitate the timely resumption of social and economic activity.

A nuclear or radiological emergency should not be terminated until the necessary urgent protective actions and early protective actions have been implemented.

When deciding on the termination of a nuclear or radiological emergency, some of the urgent protective actions and early protective actions (e.g. evacuation) might be already under consideration to be adapted or lifted. Other actions (e.g. restrictions on food, milk and drinking water) might remain in place in the longer term after the termination of the emergency, and some actions, such as iodine thyroid blocking, might already have been implemented and require no further consideration in the transition phase.

Before the termination of the emergency, the exposure situation should be well understood and confirmed to be stable, meaning that the source has been brought under control, no further significant accidental releases or exposures resulting from the event are expected and the likely future development of the situation is well understood.

Before the termination of the emergency, the radiological situation should be well characterized, exposure pathways should be identified and doses[22] should be assessed for affected populations[23] (including those population groups most vulnerable to radiation exposure, such as children and pregnant women). This characterization should consider the impact of lifting and adapting the protective actions implemented earlier in the emergency response and, where applicable, possible options for the future use of land and water bodies (e.g. imposing restrictions or identifying alternative ways in which the land and water bodies can be exploited).

Before any decision to terminate the emergency is made, a thorough hazard assessment should be performed in respect of the situation and its future development, consistent with Requirement 4 of GSR Part 7. The hazard assessment should provide a basis for preparedness and response for any new emergency that may occur.

On the basis of the hazard assessment, those events and associated areas that may warrant protective actions and other response actions — including those that may mitigate the consequences

[22] Effective dose, equivalent dose to a tissue or organ, or relative biological effectiveness weighted absorbed dose to a tissue or organ, as appropriate. See GSG-2.

[23] Including the public, workers (including emergency workers), helpers and patients, as appropriate.

of a future emergency — should be identified, and the existing emergency arrangements should be reviewed. The review should determine whether there is a need to revise the existing emergency arrangements and/or to establish new arrangements.

For example, the hazards associated with a nuclear power plant in normal operation and its associated emergency arrangements will differ from the hazards associated with an accident damaged nuclear power plant and its associated emergency arrangements.

The emergency should not be terminated until revised or new emergency arrangements have been formulated and have been coordinated among the relevant response organizations. However, in some cases, the formal establishment of revised or new emergency arrangements might be a lengthy process. Therefore, the establishment of an interim response capability in the transition phase should be considered to prevent unnecessary delay in the termination of the emergency.

The purpose of such an interim response capability is to provide an improved response to any future emergency, postulated on the basis of the hazard assessment, before the full emergency arrangements are put in place. This interim capability might not be optimal and would need to make use of all available means and resources with only minimal additional arrangements (e.g. training, a few revised procedures).

Before the termination of the emergency, it should be confirmed that the requirements for occupational exposure in planned exposure situation established in Section 3 of GSR Part 3 can be applied for all workers who will be engaged in recovery operations (see para. 5.101 of GSR Part 7) and that the source is secured in a good manner.

Paragraph 5.26 of GSR Part 3 requires that employers «ensure that the exposure of workers undertaking remedial actions is controlled in accordance with the relevant requirements on occupational exposure in planned exposure situations».

The radiological situation should be assessed, as appropriate, against reference levels, generic criteria, operational criteria and dose limits, to determine whether the relevant prerequisites for the transition to either an existing exposure situation or a planned exposure situation, as appropriate, have been achieved.

Non-radiological consequences (e.g. psychosocial and economic consequences) and other factors (e.g. technology, land use options, availability of resources, community resilience[24], the availability of social services) relevant to the termination of the emergency should be identified, and actions to address them should be considered.

A registry of those individuals[25] who, by the time the emergency is to be terminated, have been identified as requiring longer term medical follow-up (see GSR Part 7 and GSG-2) should be established before the termination of the emergency.

Consideration should be given to the management of any radioactive waste arising from the emergency, as appropriate, before the termination of the emergency.

Consultation with interested parties is required before the termination of the emergency. This process should not unduly impede timely and effective decision making by the responsible authority with respect to the termination of the emergency; however, this process is intended to help increase the public trust in and the public acceptance of the decision to terminate the emergency.

Before the termination of the emergency, the following should be discussed with and communicated to the public and other interested parties, as appropriate (see Fig. 3):

a) The basis and rationale for the termination of the emergency and an overview of the actions taken and the restrictions imposed;

b) The need to adjust imposed restrictions, to continue protective actions or to introduce new protective actions, as well as the expected duration of these actions and restrictions;

c) Any necessary modifications to people»s personal behaviours and habits;

d) Options for the implementation of self-help actions[26], as appropriate;

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[24] Community resilience is the capacity of a community to be able to recover quickly and easily from the consequences of a nuclear or radiological emergency.

[25] Including the public, workers (including emergency workers), helpers and patients, as appropriate.

e) The need for continued environmental monitoring and source monitoring after the termination of the emergency;

f) The need for continued efforts to restore services and workplaces;

g) Radiological health hazards associated with the new exposure situation.

Transition to a planned exposure situation

In addition to the general prerequisites (paras 3.6–3.18 GSG-11), the following specific prerequisites should be met in order to be able to declare the termination of an emergency and to move to a planned exposure situation:

- The circumstances that led to the emergency have been analysed, corrective actions have been identified and an action plan has been developed for the implementation of corrective actions by the respective authorities, as applicable, in relation to the facility, activity or source involved in the emergency. However, in some cases, the formal analysis and development of the action plan might be a lengthy process. Therefore, consideration should be given to establishing administrative procedures that limit or prevent the use or handling of the source until the circumstances that led to the emergency have been better understood, with the aim of preventing unnecessary delays in the termination of the emergency.
- Conditions have been assessed to ensure compliance with the safe and secure handling of the source involved in the emergency in accordance with the national requirements set forth for the respective planned exposure situation. Depending on the type of emergency, the planned exposure situation can be associated with the normal operation of the facility or activity, with cleanup and decommissioning, or with the ending of the operational life of the source involved in the emergency.
- Compliance has been confirmed with the dose limits for public exposures in planned exposure situations and with the requirements for medical exposure established in Section 3 of GSR Part 3.

Transition to an existing exposure situation

In addition to the general prerequisites (paras 3.6–3.18 GSG-11), the following specific prerequisites should be met in order to be able to declare the termination of an emergency and to move to an existing exposure situation:

a) Justified and optimized actions have been taken to meet the national generic criteria established to enable the transition to an existing exposure situation, with account taken of the generic criteria provided in appendix II to GSR Part 7, and it has been verified that the assessed residual doses approach the lower bound of the reference level for an emergency exposure situation (The residual dose is the “dose expected to be incurred after protective actions have been terminated (or after a decision has been taken not to take protective actions)

b) Areas have been delineated that are not permitted to be inhabited and where it is not feasible to carry out social and economic activity. This delineation relates to areas that, earlier in the emergency response, were subject to evacuation and/or relocation, and/or where specific restrictions were imposed that will continue to be implemented after the termination of the emergency.

c) For these delineated areas, administrative and other provisions have been established to monitor compliance with any restrictions imposed.

d) Before the termination of the emergency, a strategy has been developed for the restoration of infrastructure, workplaces and public services (e.g. public transportation,

[26] Examples of self-help actions include, but are not limited to, avoiding prolonged visits to certain areas, changing farming practices and land use, and reducing the consumption of certain foods.

shops and markets, schools, kindergartens, health care facilities, and police and firefighting services) necessary to support normal living conditions in the affected areas, such as those areas in which evacuations or relocations were carried out.

e) A mechanism and the means for continued communication and consultation with all interested parties, including local communities, have been put in place.
f) Before the termination of the emergency, any change or transfer of authority and responsibilities from the emergency response organization to organizations responsible for the long term recovery operations has been completed.
g) The sharing of any information and data that were gathered during the emergency exposure situation and that are relevant for long term planning has been organized among the relevant organizations and authorities.
h) Development of a long term monitoring strategy in relation to residual contamination has been initiated.
i) A programme for longer term medical follow-up for the registered individuals has been developed.
j) A strategy for mental health and psychosocial support for the affected population has been developed.
k) Consideration has been given to the compensation of victims for damage due to the emergency so as to provide for public reassurance, notwithstanding the fact that the processes for compensation will extend after the emergency is terminated.
l) a time frame in the range of a day to a few weeks may be adequate for terminating a small scale emergency (e.g. a radiological emergency during transport or a radiological emergency involving a sealed dangerous source).

Arrangements for the transition phase

Authority, responsibilities and management

GSR Part 7 states that:

- “The government shall make adequate preparations to anticipate, prepare for, respond to and recover from a nuclear or radiological emergency at the operating organization, local, regional and national levels, and also, as appropriate, at the international level. These preparations shall include adopting legislation and establishing regulations for effectively governing the preparedness and response for a nuclear or radiological emergency at all levels” (para. 4.5 of GSR Part 7).
- “The emergency arrangements shall include clear assignment of responsibilities and authorities, and shall provide for coordination…in all phases of the response” (para 6.5 of GSR Part 7).
- “The government shall ensure that all roles and responsibilities for preparedness and response for a nuclear or radiological emergency are clearly allocated in advance among operating organizations, the regulatory body and response organizations” (para. 4.7 of GSR Part 7).
- “The government shall ensure that response organizations, operating organizations and the regulatory body have the necessary human, financial and other resources, in view of their expected roles and responsibilities and the assessed hazards, to prepare for and to deal with both radiological and non-radiological consequences of a nuclear or radiological emergency, whether the emergency occurs within or beyond national borders” (para. 4.8 of GSR Part 7).
- *“**The government shall ensure that arrangements are in place for operations in response to a nuclear or radiological emergency to be appropriately managed**” (Requirement 6 of GSR Part 7).*

- “The arrangements for delegation and/or transfer of authority shall be specified in the relevant emergency plans, together with arrangements for notifying all appropriate parties of the transfer” (para. 6.6 of GSR Part 7).

In consideration of the prerequisites, the government should review and revise at the preparedness stage, as appropriate:

- The legal and regulatory framework governing preparedness and response in respect of the transition phase of a nuclear or radiological emergency;
- The framework for radiation protection and safety relating to longer term issues associated with an existing exposure situation, to ensure a smooth transition and to avoid unnecessary delays due to legal and regulatory issues.

As part of the review, the need for the following should be identified:

- The positions to be staffed to implement the necessary activities in the transition phase and, over the longer term, in a planned exposure situation or an existing exposure situation, as appropriate;
- The provision of «just in time» training to emergency workers and helpers;
- The mobilization of resources among relevant organizations.

Arrangements should be established to ensure that such positions, training and resources will be in place when they are needed.

Authority, role and responsibilities

In the urgent response phase, the discharge of authority and the assumption of responsibilities in the emergency response have to be, to the extent possible, straightforward and based on planned arrangements to enable the effective implementation of precautionary urgent protective actions and urgent protective actions. Thus, the input from other organizations into the decision making process regarding the emergency response actions warranted during the urgent response phase is expected to be limited.

As the emergency evolves, the focus of the emergency response will shift from bringing the situation under control and taking public protective actions, to allowing the timely resumption of social and economic activity. At this time, radiological considerations will be only one of the many factors to be evaluated in the decision making processes. Decision making at this time will require the involvement of additional organizations, with relevant responsibilities at different levels, that might not necessarily have been directly engaged during the urgent response phase. These organizations should gradually be involved, when appropriate, in the emergency response in order to discharge their allocated roles and responsibilities. This involvement should be arranged in a way that enables ongoing response efforts to continue without interruption on a routine basis in the longer term, after the emergency response organization has been relieved of its duties.

The authority, roles and responsibilities of all organizations with regard to preparation, response and recovery in the transition phase — including oversight of the implementation of provisions within the legal and regulatory framework, as well as ensuring the necessary resources (human, technical and financial) should be identified at the preparedness stage. The identification of these elements should be based on the activities that are expected to be carried out during the transition phase to fulfil the prerequisites set out in Section 3 GSG-11. As part of these arrangements, the authority and responsibility for making a formal decision on the termination of a nuclear or radiological emergency should be clearly allocated, well understood and documented in the respective emergency plans and procedures. Consideration should be given to the fact that the organization with the authority and responsibility for deciding on the transition from an emergency exposure situation to an existing exposure situation or a planned exposure situation may differ between the on-site areas and off-site areas.

A mechanism should be put in place at the preparedness stage that would allow for the mobilization and coordination of different organizations at different levels, provide for any necessary change in authority and discharge of responsibilities during the transition phase, and enable the prompt resolution of any conflicting responsibilities. This mechanism should take into account that, in the transition phase, there will be a need for multidisciplinary contributions, including those from the operating organization, which will need to be channelled efficiently and effectively.

In the transition phase, the necessary transfer of responsibilities to different jurisdictions or different authorities (or to different units within an organization) should be carried out in a formal, coordinated and fully transparent manner and should be communicated to all interested parties.

Management

The differences in management necessary for the various phases of a nuclear or radiological emergency should be identified at the preparedness stage. During the transition phase, the emergency response organization that was established in the emergency response phase should gradually return to routine (non-emergency) duties, so that the organizations with the relevant authority, roles and responsibilities can take over the activities on a routine basis within the planned exposure situation or existing exposure situation.

With the formal termination of the emergency, the structure of the emergency response organization should be deactivated. At that stage, the management structure of the various response organizations should revert to what it had been prior to the emergency to allow for an effective response to any emergency that might occur in the future; however, some of these organizations may need to assume additional responsibilities. There may also be a need for new coordination and consultation mechanisms for those organizations dealing with the consequences of the emergency in the longer term as an existing exposure situation or a planned exposure situation.

Consideration should be given to the need for the simultaneous existence of different management structures in different geographical areas owing to the gradual change in management during the transition phase.

The organizations assuming responsibility for the activities in the transition phase, and in the longer term within an existing exposure situation, as appropriate, should quickly develop an understanding of the situation. Arrangements should be established that would allow for the relevant information and data on the nuclear or radiological emergency to be made available to these organizations, including, for example, the protection strategy implemented in the emergency response phase and the rationale supporting the decisions made in the emergency response phase.

As part of the arrangements referred to in para. 4.13 GSG-11:

- The types of information and data from the emergency response phase that may be of relevance to the transition phase as well as in the longer term should be clearly identified.
- Relevant organizations that will need access to such information and data should be identified.
- A mechanism should be established to record such information and data during the emergency response phase and to exchange this information and data efficiently between the relevant organizations, taking into account the need for continued data collection and sharing in the transition phase as well as in the longer term.
- Consideration should be given to ensuring an overlap, for an agreed period, of management and technical personnel involved in the emergency response phase and those to be involved in the transition phase to ensure continuity between the two phases.

Implementation of the protection strategy in the transition phase

As soon as the emergency has been declared, the prompt implementation of the protection strategy is paramount to provide the best level of protection under the circumstances, even if very little information is available, as may be the case during the urgent response phase. As the emergency evolves, and particularly during the transition phase, more information on the circumstances that led to the emergency and its consequences will become available.

The implementation of the protection strategy should be continually reassessed, and the protection strategy should be adapted on the basis of the prevailing conditions.

The effectiveness of the protection strategy in the transition phase should be assessed against the pre-established prerequisites for the termination of the emergency. This assessment should include a comparison of the residual doses among affected populations against the chosen reference level. The process of reassessment and adaptation of the protection strategy during the transition phase should allow for iterative application of the processes of justification and optimization (Fig. 17).

The rationale for adapting the protection strategy should be transparent with respect to the criteria and conditions considered (including radiological factors and other factors) and should be documented and communicated to relevant authorities and relevant interested parties.

In the transition phase there is likely to be a gradual increase in both the need to engage with interested parties and their interest in the decision making processes. Although relevant interested parties are required to be engaged with and consulted, the process should be such that the responsibility for timely decision making clearly remains with the relevant authorities. In the transition phase, consideration should be given to the time allocated for such engagement and consultation and to the need for timely and effective implementation of the protection strategy.

Justification and optimization

Non-radiological factors become an increasingly important input into decision making in the transition phase as the doses tend to decrease with the effective implementation of the protection strategy. Notwithstanding the need to consider both radiological and non-radiological factors in the justification and optimization of the protection strategy, for situations involving higher doses (approaching or exceeding an effective dose of 100 mSv per year), protective actions are almost always justified and the radiation protection considerations generally outweigh the non-radiological impacts.

Examples of unjustified actions at this level of dose would include the unsafe evacuation of patients (e.g. the evacuation of seriously ill patients without ensuring the provision of continuous medical care) from hospitals in areas where evacuation has been ordered.

The processes of justification and optimization should consider a variety of factors. In order to take this range of factors into account, the processes for justification and optimization of the protection strategy should be such that input can be obtained from relevant authorities and relevant interested parties.

While some of the factors to be considered in the processes of justification and optimization can be known or estimated at the preparedness stage, some of them cannot be known or may be known without sufficient accuracy. Examples of such factors include seasonal and weather conditions, the occurrence of simultaneous or sequential events that may have caused a major loss of essential infrastructure (such as a conventional emergency), the actual radionuclides involved and the different lifestyles and dietary habits of the population.

The processes of justification and optimization should recognize such uncertainties and limitations in terms of the information available at the preparedness stage and should ensure that these uncertainties are adequately reflected in the estimated impact of an emergency and are appropriately considered during the response.

In all phases of an emergency, and especially in the transition phase, the processes of justification and optimization of the protection strategy should be conducted to continually assess the impact of the protection strategy on the overall radiological situation, including the assessment of (a) the residual doses incurred by people compared with the reference levels, (b) the impact on society and (c) other non-radiological impacts. Such continual reassessment should demonstrate the progress made in achieving the prerequisites for terminating the emergency and should lead to an adaptation of the protection strategy, when necessary, to allow the relevant prerequisites (see Fig. 17).

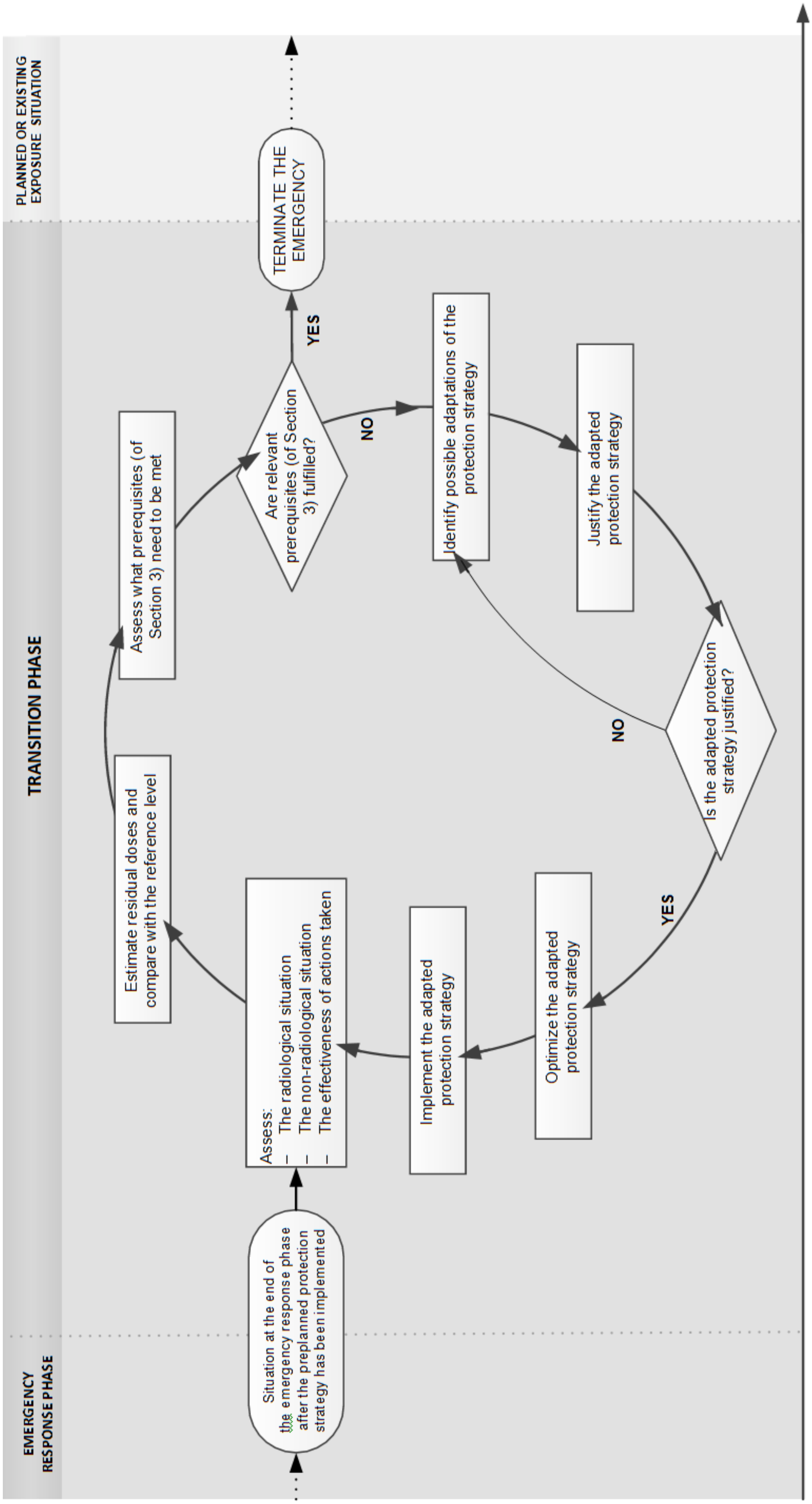


Fig. 17. The iterative process of assessing the implementation and adaptation of the protection strategy in the transition phase

Reference levels

For emergency exposure situations, GSR Part 7, GSR Part 3 require that the typical reference level expressed in terms of residual dose be set, typically as an effective dose in the range 20 to 100 mSv, acute or annual, which includes dose contributions via all exposure pathways.

For emergency exposure situations that may result in doses over a period of less than one year, the residual dose will be the total dose from all exposure pathways for the entire duration of the emergency. For a large scale emergency resulting in longer term exposures due to residual radioactive material in the environment, the residual dose will encompass the total dose from all exposure pathways over one year from the onset of the emergency. For residual doses to be used during the response, the total residual dose includes the doses received from all exposure pathways (received dose) and the doses expected to be received in future (projected residual dose), with account taken of the implementation of the protection strategy, if any.

Above this level, it is judged to be inappropriate to allow exposures to occur as a result of the exposure situation (i.e. an upper constraint on optimization). The residual dose expresses the accumulated exposure from the initiation of the event through a specified period of time, with account taken of the implementation of the protection strategy, if any.

Reference levels are used as a tool in the optimization of the protection strategy so that any optimization of protection gives priority to reducing exposures that are above the reference level; the optimization of protection should continue to be applied below the reference level as long as this optimization is justified (i.e. it has been demonstrated that the strategy subject to optimization does more good than harm). Exposures above 100 mSv are justified under some circumstances, either because the exposure is unavoidable or because in exceptional situations the expected benefits clearly outweigh the health risks. Such a situation would apply, for example, to seriously ill patients when their evacuation would present a higher risk to their health than the dose they are likely to receive by remaining in place until their safe evacuation can be arranged.

The reference level should also serve as a benchmark for retrospective assessment of the effectiveness of the actions and the protection strategy applied in the response. This comparison should be used to identify the need to adapt the protection strategy to address the prevailing conditions. In this process, further protective actions should be determined and implemented so that they are focused, as a priority, on those groups or individuals whose doses exceed the reference level. The available resources should then be allocated accordingly.

The decision to select specific numerical values for the national reference level remains the responsibility of the relevant national authority. This selection will depend on a range of circumstances, including national and local conditions (e.g. the prevailing economic and societal circumstances, and the available national, regional and local resources and capabilities), the phase of the emergency under consideration, the practicality of reducing or preventing exposures and the availability of options to reduce or prevent exposures. The process of selecting specific numerical values for the national reference level should be based on the results of the hazard assessment and consideration of the urgent protective actions, early protective actions and other response actions implemented, as well as the projected long term development of the exposures. When selecting the values for reference levels, it should be considered that selecting a value close to the lower bound will not necessarily provide for better protection when other factors (see Annex II) are also considered in the overall processes of justification and optimization.

The following two examples aim to clarify the process of applying the concept of the reference level for residual dose during the transition phase of a large scale emergency and of a small scale emergency:

An emergency involving large scale contamination resulting in exposures of the public due to long-lasting residual radioactive material in the environment will result in longer term exposures, which are expected to decrease with time. The time dependence of the reduction of the residual doses will depend on various circumstances, including the effectiveness and the efficiency of the implementation of the protection strategy. Successful implementation of the protective strategy will lead to residual doses approaching an effective dose of 20 mSv per year, which is expected to facilitate efforts aimed at enabling the transition to an existing exposure situation.

An emergency involving a dangerous source that does not result in long-lasting residual radioactive material in the environment will not result in a need for the residual dose to be gradually reduced, as in the example in para. 4.56 GSG-11. As such, while the reference level for the emergency exposure situation may be selected from the range proposed (see para. 4.52 GSG-11) for the purpose of the response, once the source is recovered safely, the concept of the reference level will no longer apply, as the situation will return to a planned exposure situation.

In general, a reference level of the magnitude used in an emergency exposure situation will not be acceptable as a long term benchmark for an existing exposure situation (see paras 4.29 and 4.54 GSG-11). Termination of an emergency should not be considered if the annual effective dose (residual dose) to the affected population who remain living in an area that is under an emergency exposure situation would be close to the upper end of the range of the reference level for the emergency exposure situation.

In exceptional cases, however, when no justified and optimized actions can be taken to further minimize the residual doses, a value for the reference level exceeding the lower end of the range of the typical reference level for an emergency exposure situation (which is the upper bound for an existing exposure situation) can be selected for the termination of the emergency, after consultation with all parties concerned. In this case, efforts should be continued to investigate the possible options for reducing doses and to further assess and minimize, as far as practicable and reasonable, the exposures of the people affected. These efforts may include providing advice and support to individuals to help minimize their exposures (e.g. advising on self-help actions).

A residual dose that is approaching the lower end of the range for the reference level for an emergency exposure situation (on the order of 20 mSv effective dose in a year (see Table 16)) should be accepted for the termination of the emergency; continued efforts will likely be necessary to progressively reduce doses further in the longer term.

After termination of the emergency and transition to an existing exposure situation, the reference level for the residual dose in an existing exposure situation should be applied in the range of 1 to 20 mSv per year, as required by GSR Part 3 (see Table 16). The International Commission on Radiological Protection recommends that the reference level for the optimization of the protection strategy is selected from the lower end of the 1–20 mSv per year range as a long term objective for existing exposure situations. Further guidance can be found in WS-G-3.1 and GSG-8.

Table 16

Overview of the applicability of reference levels for different exposure situations

Range of the reference level for the residual dose	Applicability
20–100 mSv[a]	Emergency exposure situation
~20 mSv[b]	Transition from an emergency exposure situation to an existing exposure situation
1–20 mSv[b]	Existing exposure situation

a Acute or annual effective dose.
b Annual effective dose.

What is feasible to achieve in a given time frame may differ from area to area. It may be necessary to apply different reference levels as benchmarks for the optimization process and for enabling the transition to an existing exposure situation in different geographical areas at the same time. Interested parties, including the public from the areas affected, should be informed about the rationale for such differences.

Adaptation and lifting of the protective actions

The transition phase is characterized by a change in approach, from a strategy predominantly driven by urgency to a strategy based on more comprehensive assessments aimed both at reducing longer term exposures and improving living conditions. The protection strategy already in place will probably need to be adjusted to identify where and for whom new protective actions are necessary; those protective actions that are no longer necessary are then lifted or adapted. For example, some of the urgent protective actions implemented as a precaution might be lifted if further assessment indicates that these actions are no longer justified. A decision that certain protective actions are no longer justified might be based on the positive evolution of the situation and the return to safe conditions or it might be based on evidence that the protective action was not necessary because the impact of the emergency was limited.

Adaptation or lifting of protective actions in the transition phase should be justified and optimized on the basis of the prevailing conditions, with account taken of the results of the detailed characterization of the exposure situation and exposure pathways (paras 4.142–4.157 GSG-11) and a range of radiological and non-radiological considerations.

Decisions on the adaptation and/or lifting of protective actions (e.g. lifting orders for evacuation, relocation or restrictions on certain foods for consumption) should be made after the impact on the residual doses among the affected population has been assessed.

To initiate discussions and enable decisions to be made on the adaptation or lifting of protective actions in the transition phase, OILs should be established at the preparedness stage, with account taken of the default OILs provided in the Appendix GSG-11. The pre-established OILs should be used to consider which specific protective actions may need to be lifted or adapted, when those protective actions may need to be lifted or adapted and for whom the protective actions many need to be lifted or adapted. After this preliminary screening, the final decision on the adaptation or lifting of protective actions should be based on an assessment of the residual dose (para. 4.74 GSG-11) from all exposure pathways against the pre-set reference level for enabling the transition (para. 4.57 GSG-11).

As the prevailing conditions may vary within an affected area, consideration should be given to the fact that the adaptation or lifting of protective actions may take place at different times in different locations. Overly frequent changes in the protective actions applied should be avoided, unless such changes would provide significant benefits, as frequent changes could result in a loss of public trust in the decisions of the authorities.

Before the adaptation or lifting of protective actions, the public and other interested parties should be informed about the protective actions that are to be adapted or lifted; the public and other interested parties should be told why, when and where the protective actions will be adapted or lifted and should be advised on how this adaptation or lifting will affect them.

Dose reduction considerations in the transition phase

Prevention of inadvertent ingestion and inhalation

Actions to prevent inadvertent ingestion and inhalation (e.g. washing hands and limitations on playing on the ground or on working in gardens) could be advised during the urgent response phase. However, as a protective action, advice on preventing inadvertent ingestion and the inhalation of resuspended material should also be implemented in the transition phase, on the basis of actual conditions, to reduce the residual dose among those returning to live in an affected area once evacuation or relocation is lifted.

Decontamination, control of access and other actions

Long term remediation may be needed after a large scale emergency with significant releases of radioactive material to the environment (further guidance on remediation is provided in WS-G-3.1). However, control of access, decontamination of the area or commodities and other simple dose reduction techniques should be used in the transition phase to enable the progressive lifting of protective actions such as evacuation and relocation. These actions should be considered for implementation beyond the areas where evacuation and relocation were implemented during the emergency response phase and should include areas to which people are returning (para. 4.96 GSG-11).

OILT provided in the Appendix should be used as a benchmark for screening where the actions in para. 4.96 GSG-11 may be warranted. Any decision on the implementation of such actions should give consideration to the actual residual doses against the pre-set reference level in line with the protection strategy.

Delineation of areas

Those areas identified in the transition phase that cannot be inhabited, and where social and economic activity cannot be resumed, should be delineated. Such areas should normally not be opened for people to return to live in, and administrative measures should be put in place to control access. Subject to these measures for access control, the delineation of an area as unsuitable for inhabitation should not constitute an obstacle to terminating the emergency.

Information about delineated areas and measures put in place to control access should be clearly communicated to all interested parties.

The decision to delineate areas as unsuitable for inhabitation should involve consideration of radiological aspects along with the other prerequisites mentioned in Section 3; in addition, social factors, such as public acceptance of returning to the area, should also be taken into account. Existing geographic or jurisdictional boundaries may also be considered when deciding on the delineation.

Additional preconditions for allowing people to return to an area

If people are allowed to return to an area, their well-being should not be endangered and it should be possible for them to carry out their routine social and economic activities. However, limited restrictions on normal living habits may still need to be observed and might possibly extend into the longer term. The following preconditions should be fulfilled before allowing people to return to an area from which people were evacuated or relocated:

Infrastructure and public services are in place (e.g. public transportation, shops and markets, schools, nurseries, health care facilities, police and firefighting services, water services, sanitation, energy supplies, telecommunication networks).

Clear instructions and advice on the restrictions still in place and the recommended changes to behaviours and habits, including land use, have been provided to those returning.

Public support centre(s) and informational material (e.g. leaflets, posters) for public reassurance and psychosocial support are available to those returning.

A strategy has been established for the restoration of workplaces and for the provision of social support.

Information on the likely evolution of the exposure situation and the associated health hazards has been provided to those returning.

Considerations for adapting or lifting protective actions and other response actions

The generic criteria and OILs that should be considered for initiating the adaptation or lifting of protective actions and other response actions implemented in a nuclear or radiological emergency, with account taken of the generic criteria and OILs established in GSR Part 7 and GSG-2.

National generic criteria and OILs should be established at the preparedness stage to support the adapting or lifting of specific protective actions and other response actions, with account taken of the generic criteria and OILs contained in Table 17. These pre-established OILs for the transition phase should be used to initiate considerations for adapting or lifting specific protective actions (including what protective actions may need to be lifted, when this might happen and to whom the decision may apply) in accordance with para. 4.66 GSG-11.

Following the preliminary screening based on the pre-established OILs, the decision on adapting or lifting of protective actions should be taken on the basis of an assessment of the residual dose from all exposure pathways against the pre-set reference level (see paras 4.57 and 4.74 GSG-11).

The pre-established OILs for adapting or lifting protective actions and other response actions should consider the following (Operational Intervention Levels for Reactor Emergencies, and Methodology for Their Derivation, EPR-NPP-OILs 2017, IAEA, Vienna (2017)):

- The generic criteria established in GSR Part 7 for enabling the transition to an existing exposure situation (see para. 4.64 GSG-11);
- A «ground» exposure scenario in which it is assumed that, in the affected area, all members of the public, including those most vulnerable to radiation exposure, such as children and pregnant women, will be living normally and that the lifting of restrictions on food, milk or drinking water will be implemented through the use of OIL6[27] (see Table 17);
- All individuals being exposed;
- The contribution from all relevant radionuclides and their progenies;
- The contribution from all relevant exposure pathways;
- Any behaviour of the radioactive material that will have a significant impact on the OIL value;
- The relevant effective dose (annual) and, as appropriate, calculations of the organ dose (annual or for the full period of in utero development);
- The response of monitoring instruments;
- Relevant operational requirements (e.g. usability of OILs under field conditions);
- The overall protection strategy.

A methodology that can be used to derive default OILs for enabling the transition to an existing exposure situation (i.e. the default OIL_T value) for a specific radionuclide mix is given below. The relative activity of the radionuclides in the radionuclide mix will vary over time because of processes such as radioactive decay, resulting in a time dependent $OIL_T(t, \text{mix})$, given by:

[27] The simultaneous use of OIL_T and OIL6 will ensure that all relevant exposure pathways are considered, covering the ingestion of affected food, milk or drinking water (with OIL6), external exposure from radioactive material deposited on the ground (i.e. ground shine), external exposure from resuspended radioactive material (i.e. air shine), the inhalation of resuspended radioactive material and the inadvertent ingestion of soil (e.g. from dirt on the hands) (with OIL_T).

$$\mathrm{OIL_T}(t,\mathrm{mix}) = \left(\sum_i \left(\mathrm{RA}_i(t,\mathrm{mix}) \times \mathrm{IR}_{\mathrm{grd},i}\right)\right) \times \min.\left\{ \begin{array}{l} \left(\dfrac{\mathrm{GC}(\mathrm{transition}, E, 1a)}{\sum_i \left(E_{\mathrm{grd\text{-}scenario},i}(1a) \times \mathrm{RA}_i(t,\mathrm{mix})\right)}\right), \\ \left(\dfrac{\mathrm{GC}(\mathrm{transition}, H_{\mathrm{fetus}}, 9\mathrm{mo})}{\sum_i \left(H_{\mathrm{fetus,grd\text{-}scenario},i}(9\mathrm{mo}) \times \mathrm{RA}_i(t,\mathrm{mix})\right)}\right) \end{array} \right\} \times \mathrm{WF} \quad (1)$$

where

$RA_i(t, \mathrm{mix})$ [unitless] — is the relative activity of radionuclide i at time t for a specific radionuclide mix. It is determined by $RA_i(t, \mathrm{mix}) = A_i(t, \mathrm{mix}) / \Sigma_i[A_i(t, \mathrm{mix})]$, where $A_i(t, \mathrm{mix})$ [Bq] is the activity of radionuclide *i* at time *t*, for a specific radionuclide mix;

$IR_{grd,i}$ [(Sv/s)/(Bq/m^2) or cps/(Bq/m^2)] — is the instrument response per unit ground surface activity of radionuclide *i*;

GC(transition, E, 1a) = 0.02 Sv — is the generic criterion used for transition to an existing exposure situation based on the total effective dose to the representative person over one year;

GC(transition, H_{fetus}, 9mo) = 0.02 Sv — is the generic criterion used for transition to an existing exposure situation based on the total equivalent dose to the fetus for the full period of in utero development;

$E_{grd\text{-}scenario,i}$ (1a) [Sv/(Bq/m^2)] — is the total effective dose to the representative person over 1 year for the «ground» exposure scenario, per unit ground surface activity of radionuclide *i* ;

$H_{fetus,grd\text{-}scenario,i}$ (9mo) [Sv/(Bq/m^2)] — is the total equivalent dose to the fetus for the full period of in utero development for the «ground» exposure scenario, per unit ground surface activity of radionuclide *i* ;

and WF [unitless] is a weighting factor used to allow for the quantification of other considerations. For the example values given below, the weighting factor was set to 1 for simplicity.

For a single radionuclide, Eq. (1) will result in a single time independent OIL_T value. For a single radionuclide mix, Eq. (1) will result in a time dependent $OIL_T(t)$ curve on the basis of which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. an accident at a nuclear power plant), Eq. (1) will result in a set of time dependent OILT(t, mix) curves on the basis of which a single time independent value should be chosen.

Examples of default OILT values[28] calculated using this method for a light water reactor emergency and for an emergency involving a specific radionuclide (e.g. ^{137}Cs) are given below:

- $OIL_{T,LWR}$ is 4.8 μSv/h ambient dose equivalent rate above gamma background at 1 m above ground level[29].
- $OIL_{T,Cs\text{-}137}$ is 4.8 μSv/h ambient dose equivalent rate above gamma background at 1 m above ground level.

A method for deriving a default OIL_C value for a specific radionuclide mix is given below. The relative activity of the radionuclides comprising the radionuclide mix will vary over time because of processes such as radioactive decay, resulting in a time dependent $OIL_C(t, \text{mix})$, given by:

$$\mathrm{OIL_C}(t,\mathrm{mix}) = \left(\sum_i \left(\mathrm{RA}_i(t,\mathrm{mix}) \times \mathrm{IR}_{\mathrm{comm},i}\right)\right) \times \min.\left\{ \begin{array}{l} \left(\dfrac{\mathrm{GC(commodities}, E, 1a)}{\sum_i \left(E_{\mathrm{comm\text{-}scenario},i}(1a) \times \mathrm{RA}_i(t,\mathrm{mix})\right)}\right), \\ \left(\dfrac{\mathrm{GC(commodities}, H_{\mathrm{fetus}}, 9\mathrm{mo})}{\sum_i \left(H_{\mathrm{fetus,comm\text{-}scenario},i}(9\mathrm{mo}) \times \mathrm{RA}_i(t,\mathrm{mix})\right)}\right) \end{array} \right\} \times \mathrm{WF} \quad (2)$$

where

RA_i($_t$, mix) [unitless] — is the relative activity of radionuclide i at time t for a specific radionuclide mix. It is determined by

$RA_i(t, \text{mix}) = A_i(t, \text{mix}) / \Sigma i[Ai(t, \text{mix})]$,

where $A_i(t, \text{mix})$ [Bq] is the activity of radionuclide *i* at time *t*, for a specific radionuclide mix;

$IR_{comm,i}$ [(Sv/s)/(Bq/m^2) or cps/(Bq/m^2)] — is the instrument response per unit activity of radionuclide *i* on the non-food commodity»s surface;

GC(commodities,E,1a) = 0.01 Sv — is the generic criterion for non-food commodities based on the total effective dose to the representative person over one year;

GC(commodities,H_{fetus},9mo) = 0.01 Sv — is the generic criterion for non-food commodities based on the total equivalent dose to the fetus over the period of in utero development;

$E_{comm\text{-}scenario,i}$ (1*a*) [Sv/(Bq/m^2)] — is the total effective dose to the representative person over 1 year for a «non-food commodities» exposure scenario, per unit activity of radionuclide i on the non-food commodity»s surface;

and $H_{fetus,comm\text{-}scenario,i}$ (9mo) [Sv/(Bq/m^2)] is the total equivalent dose to the fetus over the period of in utero development for the «non-food commodities» exposure scenario, per unit activity of radionuclide i on the non-food commodity»s surface.

[28] For a nuclear or radiological emergency involving a large scale release of radioactive material to the environment. The contributions from the progenies that are in equilibrium with the respective radionuclides were also considered (App. GSG-11).

[29] OILT,LWR is OILT for a release of radioactive material resulting from a severe emergency at a light water reactor or its spent fuel, in accordance with the assumptions outlined in «Operational Intervention Levels for Reactor Emergencies, and Methodology for Their Derivation, EPR-NPP-OILs 2017, IAEA, Vienna (2017).

For a single radionuclide, Eq. (2) will result in a single time independent OIL_C value. For a single radionuclide mix, Eq. (2) will result in a time dependent $OIL_C(t)$ curve on the basis of which a single time independent value should be chosen. For an emergency involving a variety of radionuclide mixes (e.g. an accident at a nuclear power plant), Eq. (2) will result in a set of time dependent $OIL_{T,C}(t$, mix) curves, on the basis of which a single time independent value should be chosen.

The ambient dose equivalent rate should be the preferred quantity for ground monitoring and for monitoring commodities during a nuclear or radiological emergency. If the radionuclide or the radionuclide mix is such that the ambient dose equivalent rate is not usable (e.g. measured values are within the gamma background levels), the beta or alpha count rates should be monitored and used instead.

Table 17

Generic criteria for the projected doses and oils for initiating considerations to adapt or lift specific protective actions and other response actions

Protective action	Generic criteria for taking the action		Generic criteria for considering to adapt/lift the action		OILs for considering to adapt/lift the action	Consideration
	E^*	H_{fetus}^{**}	E^*	H_{fetus}^{**} for the full period of in utero development		
Evacuation	≥100 mSv in the first 7 days	≥100 mSv in the first 7 days	≥100 mSv in the first year	≥100 mSv	≥OIL2***	Substituting evacuation with relocation
			<100 mSv in the first year	<100 mSv	<OIL2***	Lifting the evacuation only if limited restrictions are still necessary for people living normally in the area, with account taken of (a) the actual residual doses in comparison to the pre-set reference level and (b) the preconditions referred to in para. 4.101 GSG-11
			≤20 mSv per year	≤20 mSv	$<OIL_T$ (see paras A.5 and A.6 GSG-11)	Lifting the evacuation along with the decision to terminate the emergency if the prerequisites specified in Section 3 and the preconditions referred to in para. 4.101 GSG-11 are fulfilled
Relocation	≥100 mSv in the first year	≥100 mSv for the full period of in utero development	<100 mSv in the first year	<100 mSv	<OIL2***	Lifting the relocation only if limited restrictions are still necessary for people living normally in the area, with account taken of (a) the actual residual doses in comparison to the pre-set reference level and (b) the preconditions referred to in para. 4.101
			≤20 mSv per year	≤20 mSv	$<OIL_T$ (derived on the basis of the method outlined in para. A.5)	Lifting the relocation along with the decision to transition to the emergency exposure situation if the prerequisites specified in Section 3 and the preconditions referred in para. 4.101 are fulfilled

Food, milk and drinking water restrictions in affected areas	≥10 mSv in the first year	≥10 mSv for the full period of in utero development	<10 mSv in the first year	<10 mSv	<OIL6***	Lifting the restriction only after estimation of the actual doses from the ingestion pathway and their contribution to the residual dose from all exposure pathways
Food, milk and drinking water restrictions for international trade	≥1 mSv per year	≥1 mSv for the full period of in utero development	<1 mSv per year	<1 mSv	<Guideline levels****	Lifting restrictions on international trade for infant and non-infant food in line ****
Non-food commodity restrictions in affected areas	≥10 mSv in the first year	≥10 mSv for the full period of in utero development	<10 mSv in the first year	<10 mSv	<OIL_C (derived on the basis of the method outlined in para. A.8)	Lifting the restriction only after estimation of the actual doses from the use of non-food commodities and their contribution to the residual dose from all exposure pathways
Non-food commodity restrictions in affected areas for international trade	≥1 mSv per year	≥1 mSv for the full period of in utero development	<1 mSv per year	<1 mSv	<OIL_C (derived on the basis of the method outlined in para. A.8)	Lifting restrictions on trading non-food commodities internationally

* Effective dose.
** Equivalent dose to the fetus.
*** Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).
****General Standard for Contaminants and Toxins in Food and Feed of 1995, as last amended 2013, Codex Alimentarius Commission, http://www.fao.org/fileadmin/user_upload/agns/pdf/CXS_193e.pdf

Moving from the intermediate phase to the long-term phase

Protective actions implemented during the early and intermediate phases should be lifted, adapted, or complemented when authorities and stakeholders consider that these actions have achieved their expected effect, or when their continued application is no longer justified.

Decisions on allowing those who have been temporarily relocated to return to their homes involve an extensive dialogue with the affected people and the authorities and professionals in their communities. ICRP emphasises that individuals have a basic right to decide about their future. All individual decisions about whether to remain in or leave an affected area, or to return home or not, including those of voluntary evacuees, should be respected as a matter of dignity, and supported by the authorities.

The decision by the authorities to allow people to live permanently in an area should be taken in close consultation with representatives of the local communities and all other stakeholders when the following conditions are met. Characterisation of the radiological situation of the environment, foodstuffs, goods, and people in affected areas is sufficiently well achieved. Mechanisms are established for the involvement of local stakeholders in decision-making processes. A system for radiological monitoring of the environment and measurement of individual external and internal doses has been established, as well as a health surveillance system. Appropriate mechanisms (e.g. co-expertise process) have been put in place to involve affected people in improving their well-being and quality of life.

Long-term phase

The accidents at the nuclear power plants in Chernobyl and Fukushima demonstrated that management of the long-term phase based solely on radiological principles and criteria was not sufficient to respond to the challenges faced by individuals and communities in affected areas. While radiological principles and criteria are an essential input to the management of the long-term phase, they should be used appropriately and with due flexibility to accompany the rehabilitation of the living and working conditions of affected individuals and communities.

It is the government»s responsibility to provide relevant guidance to the population on how to protect themselves, and the conditions, means, and resources to implement this protection effectively.

Protection of responders during the long-term phase

The aim on-site is to dismantle the damaged installation, including management of the corresponding waste. The exposure situation is mainly characterised and the source is mostly under control, although some technical difficulties may remain, and unforeseen situations may occur at any time. Circumstances on-site may require planning for exposures above the reference level. In that case, ICRP recommends special arrangements limited in time, which should be prepared with the greatest care after deliberation between concerned parties. The exposure of these residents should be considered as public exposure, and should be managed using the same requisites as for the general population in affected areas.

When an occupationally exposed worker is involved as a responder, the exposure received during the response should be accounted for and recorded separately from exposures received during planned exposure situations. Arrangements for dose records of responders based on agreement between the responsible authorities, operators, employers, and workers should be made in advance as part of the plan for nuclear installation accidents at the preparedness stage. ICRP recommends that occupationally exposed workers who wish to return to their regular activities when the intermediate phase is over should not be prohibited from doing so. The decision should be taken by the authority responsible for the installation on a case-by-case basis.

Protection of the public and the environment

Management of the protection of people in affected areas in the intermediate and long-term phases is a complex process involving not only radiological factors, but also societal, environmental, and economic considerations. This process includes actions implemented by national and local authorities, and self-help protective actions taken by residents of the affected areas. ICRP recommends that the authorities, experts, and stakeholders should co-operate in the so-called «co-expertise process» to share experience and information, promote involvement in local communities, and develop practical radiological protection.

Co-expertise process

This process of co-operation between experts, professionals, and local stakeholders aims to share local knowledge and scientific expertise for the purpose of assessing and better understanding the radiological situation, developing protective actions to protect people and the environment, and improving living and working conditions. The co-expertise process is effective in empowering individuals and communities affected by radiation to know how to protect themselves, and thus to develop a practical radiological protection culture needed to face the consequences of a nuclear accident. It enables people to restore their autonomy regarding decisions that affect them, which has been seriously impaired at the time of a nuclear accident. Furthermore, it contributes to reconnecting people, helps to develop their solidarity, and provides an opportunity for them to look to the future with more confidence.

Conclusions

Given the complexity of the situation created by a nuclear accident and the extent of its consequences, radiological protection only represents one dimension of the contributions that are likely to need to be mobilised to cope with the issues facing all affected individuals and organisations. They should be elaborated with the objective of putting radiological protection at the service of rehabilitating living and working conditions and the quality of life of affected communities. To achieve this objective, ICRP emphasises the crucial importance of involving stakeholders. Experts should adopt a prudent approach to manage exposures, seek to reduce inequities in exposures, take care of vulnerable groups, and respect the individual decisions of people while preserving their autonomy of choice.

PUBLIC COMMUNICATION AND PROVIDING INSTRUCTIONS

Public communication, general aspects

In developed by IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency and sponsored by 13 international organizations it was stated that planning public relations, adequately informing the population about the current situation and about the necessary measures for protection against radiation are among the main requirements of preparedness for response to a nuclear or radiological emergency, emphasizes that public relations is the responsibility of the government of the state where the event occurred, as follows:

Requirement 10 states:

"The government shall ensure that arrangements are in place to provide the public who are affected or are potentially affected by a nuclear or radiological emergency with information that is necessary for their protection, to warn them promptly and to instruct them on actions to be taken."

Requirement 13 states:

"The government shall ensure that arrangements are in place for communication with the public throughout a nuclear or radiological emergency."

Public communication is essential to the effectiveness of protective actions to mitigate adverse consequences of an emergency for human life, health, property and the environment. Effective communication with the public that is timely, clear and accurate is also important for maintaining trust on the part of the public (hereafter referred to as 'public trust'). Experience has demonstrated the importance of, and the challenges involved in, communicating with the public in a nuclear or radiological emergency. Past emergencies have had local, national, regional and international consequences and have led to high levels of public awareness and concern. This has led to greater emphasis being placed on effective public communication in preparedness and response for a nuclear or radiological emergency.

Effective public communication is dependent on the level of emergency preparedness of the States and organizations involved. Emergency preparedness includes developing a public communication programme, including a strategy and plans for being adequately prepared for public communication in a nuclear or radiological emergency.

In meeting Requirements 10 and 13 of GSR Part 7, States will contribute to fulfilling, in part, Requirement 16 of GSR Part 7, which states:

"The government shall ensure that arrangements are in place for mitigation of non-radiological consequences of a nuclear or radiological emergency and of an emergency response."

Such non-radiological consequences could include, for example, anxiety and long term psychological effects among the public. These non-radiological consequences could be mitigated by means of effective public communication on radiological health hazards and clear instructions on any protective actions to be taken.

Especially developed for that purpose Safety Guide provides specific recommendations on:

(a) A public communication programme for transparent (i.e. frank and open), timely, clear and accurate (i.e. factually correct) communication with the public;

(b) Coordination, to the extent practicable, of response organizations and other authorities providing official information;

(c) Effective messaging and consistent messages.

These recommendations are specifically aimed at organizations with roles and responsibilities in preparedness and response for a nuclear or radiological emergency. The principal users of Safety Guide are those with responsibilities for communication with the public and the news media in an emergency, including those who do not have day to day public communication tasks.

The primary purpose of public communication in emergency preparedness and response should be keeping the public informed and maintaining public trust. Public communication should also help to achieve the goals of mitigating adverse consequences of an emergency for human life, health, property and the environment, and of preparing, to the extent practicable, for the resumption of normal social and economic activity.

To help to achieve the goals of emergency response, the key objectives of public communication for a nuclear or radiological emergency should be:

(a) To protect the public;

(b) To inform the public, both at the preparedness stage and during the response, of protective actions and other response actions, and of the nature of any hazards, and to facilitate emergency response actions;

(c) To gain and maintain public trust in the emergency response by means of transparent, timely, clear and accurate public communication;

(d) To address public concerns with regard to potential adverse consequences for human life, health, property and the environment;

(e) To prevent undue concern, to mitigate anxiety and long term psychological effects, and to help to ensure that actions taken do more good than harm;

(f) To respond to misinformation and rumors;

(g) To enable interested parties to make informed decisions.

To be effective, the developed public communication programme for a nuclear or radiological emergency should ensure that public communication is transparent, timely, clear and accurate, to the extent possible. Public communication should be in plain language for a general audience. These aims might be conflicting, and professional judgment should be made about the best balance.

Public communication should be coordinated between response organizations and other authorities providing official information and should comply with national requirements on the protection of sensitive information

Communication with the public (the most active or the most concerned (because of this more aggressive) and with the population should be truthful, open, not allow false interpretation of information or its absence; give information as early as possible without allowing the possibility of gossip and falsification; media (or groups of lecturers) should be provided with truthful information and correct information; it should be presented in simple understandable language with a minimum of technical terms using intelligible comparisons, for example, comparing emergency doses with doses of medical radiation in diagnostic procedures.

Risk perception

The public perception of risk may be different from the assessments of risk provided by experts in radiation protection; this has implications for public communication during a nuclear or radiological emergency. Risk perception can be influenced by various factors, including knowledge, individual beliefs, values and norms, as well as wider societal and national aspects.

Experts in radiation protection define risk in terms of cause and effect relationships and attempt to quantify the likelihood that harm might result from radiation exposure. Members of the public take more account of qualitative factors in deciding whether they consider an involuntary risk to be acceptable. Those responsible for public communication should be aware that this tendency could mean that risks with a low estimated likelihood are perceived by the public to be high risks. "Risk” in this context means the estimated probability that a specified health effect will occur in a person or group as a result of exposure to radiation.

The health effect(s) in question need to be stated, for example risk of fatal cancer, risk of serious hereditary effects or overall radiation detriment. Risk is commonly expressed as the product of the estimated probability that exposure will occur and the estimated probability that the exposure, assuming that it occurs, will cause the specified health effect(s). The latter probability is sometimes termed the “conditional risk”. Risks can be estimated by using evidence from epidemiological investigations of disease rates in previously exposed populations (i.e. based on past observations).

To address the tendency for risks of low estimated likelihood being perceived as high risks, a process that includes regular information activities and/or regular communication with and consultation of the public should be put in place at the preparedness stage. This process should be coordinated with routine activities for communication with and consultation of other interested parties.

Informing the public most often takes place against the background of a misunderstanding by the public of the risk of exposure to ionizing radiation. The majority of the population believes that any exposure to ionizing radiation causes harmful mutations in the human body, leading to the deformity of newborns, cancer in the future, and radiation sickness soon after exposure. The horror of the atomic bombings of Japan is often recalled, which is not comparable even with major accidents of nuclear reactors due to various destructive factors (shock wave, thermal effects, fires, acute exposure in huge doses). It is useful to recall the law of nature: quantity turns into quality, i.e. small doses of radiation are harmless and sometimes beneficial, as in medical use, large doses should be avoided. If official information is late, then there is a lot of misinformation on the Internet and in the media.

It can be recalled that minimal deterministic effects in the form of a temporary change in the composition of the blood are detected at whole-body irradiation doses (effective dose) above 500 mSv once, which, for example, after the Chernobyl accident was observed only in people who struggled with the accident at the nuclear power plant site. Long-term consequences are estimated by probability.

Misinformation and rumors

Paragraph 5.74 of GSR Part 7 [1] states:

“Arrangements shall be made to identify and address, to the extent practicable, misconceptions, rumors and incorrect and misleading information that might be circulating widely in a nuclear or radiological emergency, in particular those that might result in actions being taken beyond those emergency response actions that are warranted”.

The increased anxiety felt during and in the aftermath of an accident is intensified by misinformation and rumors, which present an additional health hazard. Paragraph 5.92 of GSR Part 7 relates to mitigating of such non-radiological consequences states:

“Arrangements shall be put in place for any actions taken, beyond those emergency response actions that are warranted, by members of the public and by commercial, industrial, infrastructural or other governmental or non-governmental bodies to be, to the extent practicable, promptly identified and appropriately addressed. This shall include the designation of organization(s) with the responsibility for monitoring for, identifying and addressing such actions.”

Rumors will arise from various sources during an emergency response. Social media, which enable immediate dissemination of information — including misinformation, rumors and speculation — have made responding to misinformation and rumors in an emergency a bigger challenge.

Arrangements for responding to misinformation and rumors should be put in place to ensure that they do not lead to actions being taken by the public on the basis of incorrect or misleading information. Such actions could go beyond those emergency response actions that are warranted and could do more harm than good.

The arrangements for responding to misinformation and rumors should enable the identification of misinformation and rumors through media monitoring and the correction of incorrect and misleading information by means of public communication tools.

Role of social media when communicating to the public

Public communication tasks

The selection process for suitable individuals for core public communication tasks and for auxiliary tasks should take into account the specific skills necessary and the job descriptions for each role (e.g. spokesperson, technical briefer, public information officer), as well as the personal characteristics necessary to perform under circumstances of high demand and tremendous stress in an emergency.

The level of performance and the resilience necessary for roles in public communication should be considered. Suitable personal characteristics include the ability to be effective in difficult situations, to solve problems effectively and efficiently, and to cope in extraordinary and unpredictable circumstances (Fig. 18).

Fig. 18. Organization scheme for a Public Information Section within unified Command & Control System

Core public communication tasks

Production and writing

For efficient communication in an emergency, various materials should be prepared, to the extent possible, at the preparedness stage. These materials should include templates for press releases and statements, presentations for briefings for the news media, background information, and sample questions and answers.

Relations with traditional media and on-line news media

Relations with traditional media (e.g. the press, television and radio stations) and on-line news media should be developed and maintained to enable interactions, communication and liaison with journalists from media outlets such as newspapers, news magazines and television and radio stations, and from on-line news sites.

Key journalists and news media should be identified at the preparedness stage. Routine communication should be established with the journalists identified.

Social media

Arrangements should be made for a presence on relevant social media in an emergency to provide a means to disseminate information, to respond to misinformation and rumors, and to respond to enquiries as necessary and as possible. Organizations should be aware that a continuous presence on social media platforms (i.e. also during routine periods) significantly enhances the likelihood of effective communication on these platforms in an emergency (i.e. by increasing the experience of personnel responsible for social media and the number of followers on specific platforms).

Such arrangements should include the provision of sufficient human resources and infrastructure, and the development of standard operating procedures, including a streamlined approval process. These arrangements should enable a timely response to questions on relevant social media.

Relevant social media should be identified at the preparedness stage. The decision on which social media to use should be made on the basis of their usage and their audience.

Organizations should have clear guidelines in place for the official use of social media by members of response organizations. Organizations should have a clear code of conduct in place for the private use of social media by members of response organizations. This is because messages posted in a private capacity could be mistaken for official information if they include comments on an emergency.

Monitoring of the media

Media monitoring in a nuclear or radiological emergency is the process of reading, watching or listening to various media sources and looking for the inclusion of specific keywords or topics of interest in relation to the emergency. Media monitoring should be conducted by using appropriate resources and technical systems to monitor traditional media, on-line news media and social media.

Media monitoring should be used to obtain data for use in strategic planning for public communication, and in developing and maintaining relations with traditional media and relations on social media.

Data from media monitoring should be used to enable public information officers to know what concerns the public, which information is reaching the public, and how the information is being interpreted. The data should also be used to help to identify misconceptions, rumours, and incorrect and misleading information (i.e. misinformation) that might be circulating in an emergency.

Media monitoring should be used to provide access to potentially valuable information for the response. For example, real time information from eyewitnesses or live coverage could help by raising awareness of the situation and could help in identifying hazards and problems

Internal communication

Internal communication should be used to inform members of response organizations about an emergency and the emergency response and to meet their needs for information. Internal communication in this context should not include operational communication for organizing the emergency response. Internal communication should be considered to be a part of public communication, and it should not include confidential or proprietary information.

All members of response organizations should be able to act as channels for public communication. Arrangements should be made and should be communicated by means of internal communication to ensure that members of response organizations who are contacted by journalists know to refer such requests to the public information section.

Other public information activities

Public information activities other than those conducted to provide public information for traditional media, on-line news media and social media include, as necessary, communicating with interested parties and providing additional information on emergency preparedness and response to the public. Such activities should include, as appropriate, newsletters and two-way communication (e.g. telephone hotlines, public meetings).

On-line communication

The public information officers for on-line communication should be responsible for making messages from the response organization available on its web site. The maintenance of an emergency web page, which is activated during a severe emergency, should also be a responsibility of the public information officers responsible for on-line communication.

The public information officers responsible for on-line communication should be in close contact with the public information officers responsible for social media.

Communication on social

A strategy for public communication by means of social media should be developed and implemented at the preparedness stage. The public information officers responsible for on-line communication on social media should set up accounts for the response organization on the most relevant social media, so as to reach a maximum number of users and to gain the necessary operational experience in social media outreach and audience engagement.

Communication on the most relevant social media should be continuous, and information as part of an ongoing risk communication strategy should be regularly shared with users at the preparedness stage. This is intended to help in gaining public trust, in gaining an audience and in ensuring that the use of social media in an emergency will not be new for the public information officers.

Those responsible for public communication in an emergency should take into account that social media will be the preferred means for making enquiries and receiving information for many audiences. Social media should be used as an effective method of reducing the need for individual enquiries by other means of public communication, such as telephone hotlines and email.

Those responsible for public communication in an emergency should anticipate that answers provided to questions raised on social media will be read by other users, including users in the news media.

Telephone hotlines

Arrangements should be made at the preparedness stage to ensure the availability of telephone hotlines and of trained operators to answer telephone enquiries from the public during a nuclear or radiological emergency. The arrangements for telephone hotlines for the public communication response should be scalable to the differing nature and severity of the emergency.

Arrangements should be made at the preparedness stage for the use of prerecorded messages for telephone hotlines, and for using telephone hotlines to provide the latest press release and recent information on protective actions and other response actions.

Arrangements should be made at the preparedness stage to ensure that telephone enquiries can be dealt with in the main languages spoken by the population.

Background informational material

Background informational material in support of the public communication response should be produced at the preparedness stage.

Background informational material should be such that it can be made available on the organization's web site, in traditional media and on-line news media, at public meetings, on social media and on request. Background informational material should include a catalogue of frequently asked questions and answers.

Background informational material should include maps, graphics and basic information on nuclear energy, radiation protection, exposure pathways, protective actions and other response actions, the roles and responsibilities of response organizations and on different types of nuclear or radiological emergency. The background informational material should be regularly reviewed and revised, as appropriate.

Background informational material on the response to an emergency should be incorporated, into communication with interested parties.

Social media

Public information officers responsible for on-line communication on social media should ensure that official information on an emergency is made available on social media as early as possible.

Public information officers should ensure that communication with social media users is established and maintained, as appropriate. This communication should include links to relevant information on the emergency web page and other web sites where accurate factual content is available.

Monitoring of the media

Media monitoring for sources in traditional media, on-line news media and social media should be established or extended as soon as possible at the start of the response phase. Keywords and search terms selected at the preparedness stage should be reviewed and should be complemented as necessary with keywords particular to the emergency, such as the name of the facility or its location. Particular attention should be paid to identifiers such as 'hashtags' or similar markers used by the response organizations, the public or the news media to identify messages relating to the emergency.

Data from media monitoring should be used to identify misinformation and rumors and topics of particular interest to the public and to assess whether additional public information is necessary.

Data from media monitoring should be continually provided to the public information section and the unified command and control system.

On-line communication

All official information should be made immediately available on the organization's web site in an emergency response.

Communication on social media

Public information officers responsible for on-line communication on social media should make official information available on relevant social media at the same time as it is made available on the organization's web site and by means of other channels of communication.

Social media should be used to communicate protective actions for those directly affected by the emergency and to address concerns and questions raised on social media.

Providing instructions, warnings and other relevant information to the public

The Requirement 10 states:

The government shall ensure that arrangements are in place to provide the public who are affected or are potentially affected by a nuclear or radiological emergency with information that is necessary for their protection, to warn them promptly and to instruct them on actions to be taken.

For facilities in category I or II and areas in category V, arrangements shall be made to provide the permanent population, transient population groups and special population groups or those responsible for them and special facilities within the emergency planning zones and emergency planning distances, before operation and throughout the lifetime of the facility, with information on the response to a nuclear or radiological emergency.

This information shall include information on the potential for a nuclear or radiological emergency, on the nature of the hazards, on how people would be warned or notified, and on the actions to be taken in such an emergency. The information shall be provided in the languages mainly spoken by the population residing within the emergency planning zones and emergency planning distances. The effectiveness of these arrangements for public information shall be periodically assessed.

For facilities in category I or II and in areas in category V, arrangements shall be made to register those members of the public in special population groups and, as appropriate, those responsible for them, and to promptly issue them and the permanent population and transient population groups, as well as special facilities in the emergency planning zones and emergency planning distances, with a warning and with instructions to be followed upon declaration of a general emergency. This shall include providing instructions on the actions to be taken in the languages mainly spoken by the population.

Arrangements shall be made to explain to the public any changes in the protective actions and other response actions recommended in the State and any differences from those recommended in other States.

Arrangements shall be made to coordinate with other States in the event of a transnational emergency any protective actions and other response actions that are recommended to their citizens and to their embassies in order either to ensure that they are consistent with those recommended in other States, or to provide an opportunity for them to explain to the public the basis for any differences.

The cycle of how to effectively organize and implement the public information roles and activities described in the Action Guides and Information Sheets shown below.

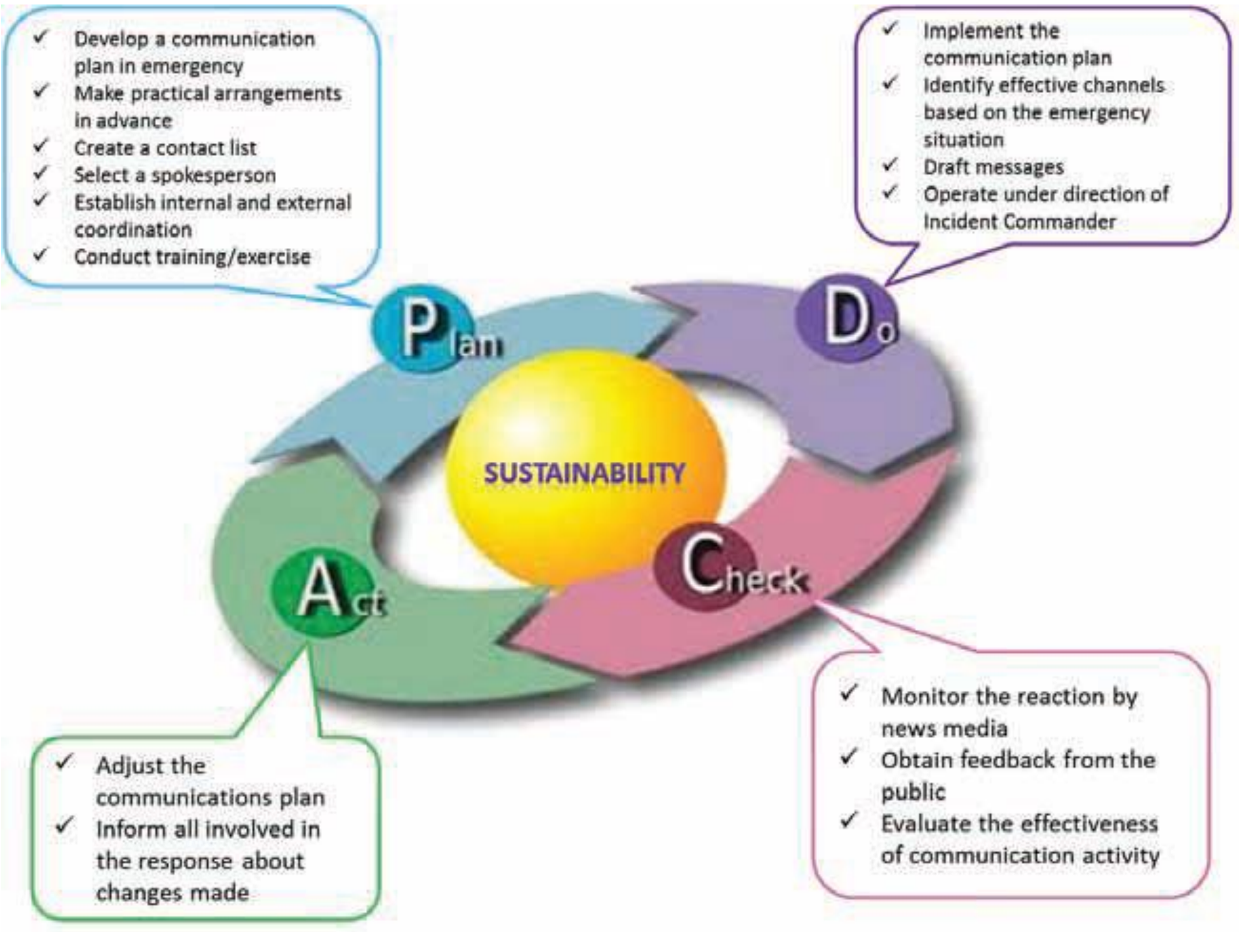


Fig. 19. Action Guides and Information Sheets

"Plan" is the preparation phase for communicating in an emergency such as development of a communication plan, procedures and practical arrangements in advance.

"Do" is the phase of implementation of communication activities by the PIO/Team in an emergency such as drafting messages and operating under the IC's direction on releasing messages to the public.

"Check" is the evaluation phase to determine the effectiveness of communication activities such as media monitoring.

"Act" is the phase of adjustment of communication activities based on the evaluation results in the "Check" phase.

Depending on the situation at a nuclear facility, the PIO communicates in different ways with the public. Figure below illustrates what is being communicated and the evolution of communication under normal and emergency circumstances.

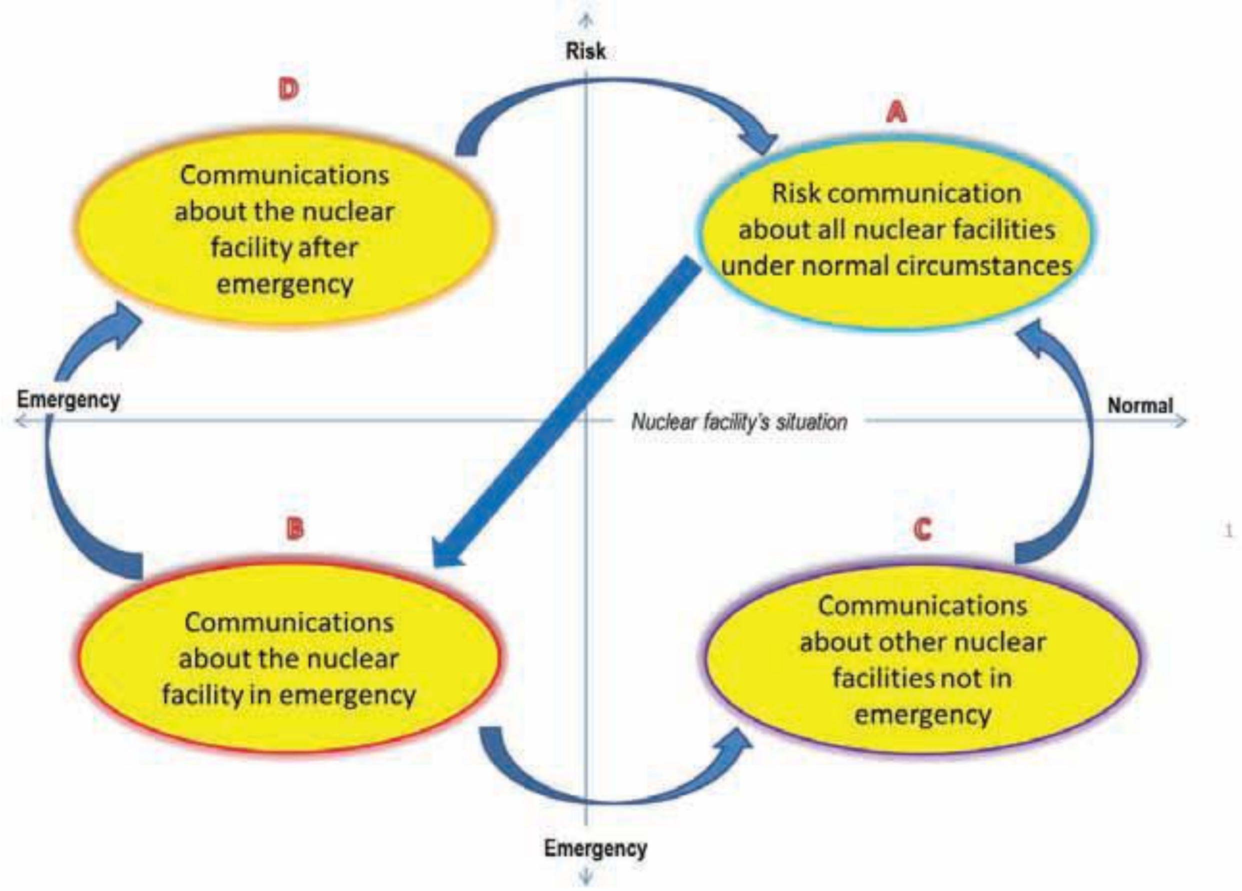


Fig 20. There is an example of Public Communication Information Sheets (PC-IS),
PC-IS.1. Communicating basics of radiation

This section provides explanations using plain language terminology about the basics of radiation so that they can be communicated to the public in an understandable way whether during the preparedness or the emergency phase.

What is radiation?

Radiation is a phenomenon in which particles with some energy travel through air or material (skin, glass, water, etc.). Radiation can have an impact on the material through which it is travelling depending on its energy. Radiation is produced by matter and this matter is generally called a source. This source can be natural or artificial (person-made).

Basic facts in plain language about sources of radiation:

- Radiation is naturally present in the environment. This is called natural background radiation.
- People are exposed to natural sources of radiation, which include cosmic rays, gamma rays from the Earth, radon decay products in the air and various radionuclides found naturally in food and drink.
- People may also be exposed to artificial sources of radiation, which include medical X rays, industrial gamma rays and fallout from the testing of nuclear weapons in the atmosphere.
- Often, medical exposures from diagnosis and in treatment account for the largest dose from artificial sources.

Developing public communication program

According to Paragraph 4.1 of GSR Part 7 which states:

"The government shall ensure that an emergency management system is established and maintained on the territories of and within the jurisdiction of the State for the purposes of emergency response to protect human life, health, property and the environment in the event of a nuclear or radiological emergency", an effective emergency management system is required to incorporate reliable public communication at all stages: the preparedness stage, the emergency response phase and the transition phase. Arrangements should be put in place at the preparedness stage for public communication during the emergency response phase and during the transition phase.

Public Communication Programme

A public communication programme is an arrangement made at the preparedness stage for organizing public communication during a nuclear or radiological emergency. It should specify the following:

(a) A public communication strategy that states the principal objectives of and approach to public communication in an emergency;

(b) A public communication plan;

(c) The necessary infrastructure and resources, based on a specified budget.

Paragraph 4.7 of GSR Part 7 states:

"The government shall ensure that all roles and responsibilities for preparedness and response for a nuclear or radiological emergency are clearly allocated in advance among operating organizations, the regulatory body and response organizations.

This also includes the allocation of roles and responsibilities, as appropriate, among members of the government."

The public communication programme should be prepared in advance in accordance with the allocation of roles and responsibilities, and in coordination with the regulatory body and all responsible operating organizations and response organizations within a unified command and control system. The public communication programme should be evaluated and updated at regular intervals. Any transfer of responsibilities for public communication in the transition phase should be considered at the preparedness stage and should be included in the public communication programme.

The public communication programme, including the necessary resources, should be approved by response organizations. Appropriate human resources and financial resources should be allocated on a continuing basis for the purpose of ensuring preparedness and maintaining a high level of readiness for an emergency response.

At the preparedness stage, the public communication programme should identify all practical arrangements and logistics necessary for a public communication strategy and a public communication plan. These arrangements will support public communication during the response to a nuclear or radiological emergency.

A public communication programme should be developed in a State irrespective of whether it has a nuclear power programme: an emergency involving a radioactive source could occur in any State. Experience has demonstrated that an emergency at a facility in one State could have effects on the public in other States. Possible effects include non-radiological consequences, such as anxiety among the public, as well as economic and commercial consequences, such as disruption to shipping and commercial airline flights.

Public Communication Strategy

Paragraph 5.69 of GSR Part 7 states that "Communication with the public in a nuclear or radiological emergency shall be carried out on the basis of a strategy to be developed at the preparedness stage as part of the protection strategy." The public communication strategy should be developed and applied at the preparedness stage in order to identify key issues and target audiences, to prepare appropriate messages and to carry out communication activities.

The public communication strategy, and the public communication plan that is formulated from this strategy, should be based on a graded approach. The graded approach should be applied to public communication on the basis of the characteristics of the emergency, the magnitude of its actual or expected consequences and its significance for the public.

The elements of a public communication strategy should include the following:

a) A description of all relevant scenarios for hazard assessment;

b) Strategic considerations determining the main challenges for public communication for each scenario;

c) Specific objectives for the public communication response for each scenario, with account taken of the strategic considerations in achieving the goals of emergency response and the key objectives of public communication;

d) An identification of the key target audiences for each scenario;

e) Key messages for each scenario that can be prepared at the preparedness stage in support of achieving the public communication objectives for the scenario;

f) The recommended approach for the most effective performance of public communication tasks and the use of public communication tools;

g) Any expected transfer of responsibilities for public communication in the transition phase.

The context in which the public communication strategy is to be applied should be considered. Surveys should be made of the perception of risks and the information needs of the public, both at a national level and among the population potentially affected in areas around nuclear facilities or around facilities in which radiation sources are used. On the basis of information obtained in these surveys, a public awareness programme should be established to provide information in plain language at the preparedness stage. The information provided should cover how the response to a nuclear or radiological emergency would be conducted and how the public would be protected.

The information should be made available to the population within the emergency planning zones and emergency planning distances to assist the public in making informed decisions on protective actions or other response actions in an emergency response.

Paragraph 5.69 of GSR Part 7 states that “These arrangements shall take into account the need to protect sensitive information in circumstances where a nuclear or radiological emergency is initiated by a nuclear security event.” Arrangements for public communication in an emergency initiated by a nuclear security event should be established at the preparedness stage.

All arrangements for public communication as outlined in the public communication strategy should be explained and described in the public communication plan.

Public Communication Plan

Requirement 23 of GSR Part 7 states:

“The government shall ensure that plans and procedures necessary for effective response to a nuclear or radiological emergency are established.”

Arrangements should be made to develop a public communication plan for a nuclear or radiological emergency on the basis of the public communication strategy.

The public communication plan for an emergency:

- should apply the public communication strategy, with account taken of emergency scenarios derived from relevant hazard assessment scenarios;
- should set out a clear framework and an organizational structure for public communication;

- should allocate responsibilities, goals and tasks within the organizational structure for the public communication response;

- should provide operational guidelines for an appropriate public communication response to a nuclear or radiological emergency.

A public information officer should be assigned responsibility for strategic planning for public communication. The purpose of strategic planning is to enable the public communication response to draw upon the resources stipulated in the public communication strategy and the public communication plan as necessary, under the specific circumstances of the emergency.

A public communication plan should include the following:

a) A description of the organizational structure and responsibilities for the public communication response;

b) A description of the concept of operations for communicating with the public during an emergency;

c) A description of the available infrastructure and resources;

d) A list of possible spokespersons and technical briefers (i.e. technical experts for the preparation of briefing materials) who have already been identified;

e) A description of the tasks for public communication and a plan for allocating these tasks to staff;

f) An operational manual specifying actions to be taken for public communication in an emergency and the stage at which they should be taken, based on the use of public communication tools;

g) A description of any expected transfer of responsibilities for public communication in the transition phase.

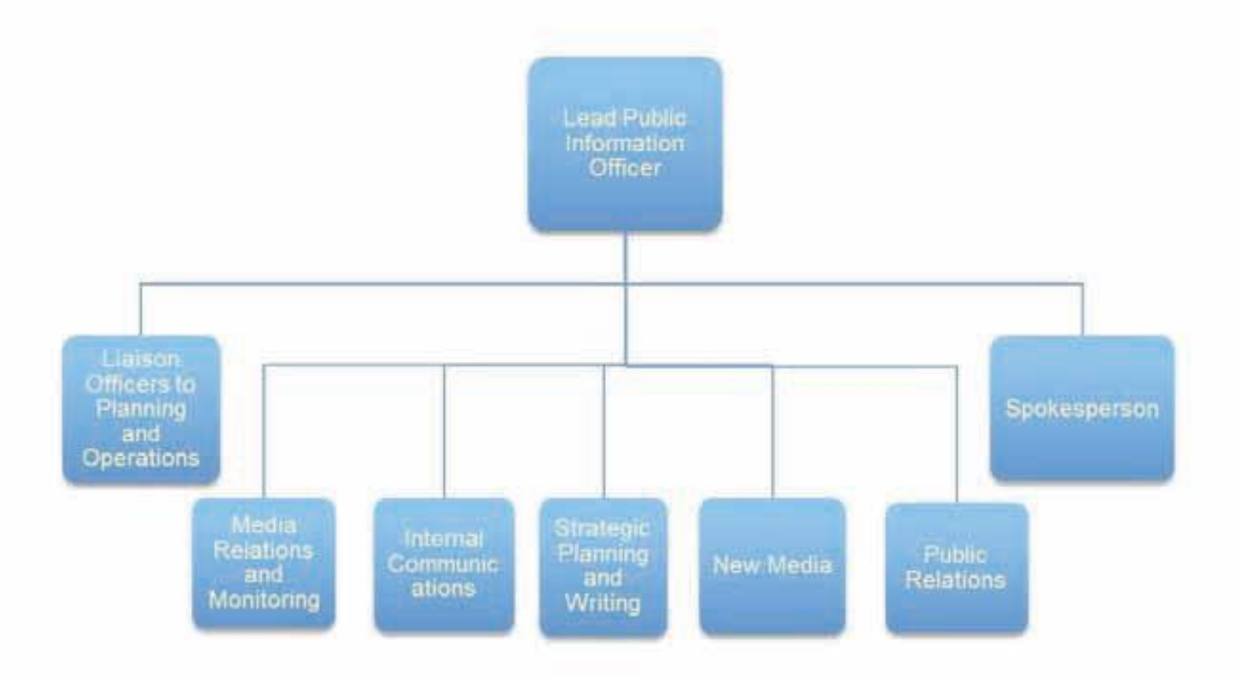


Fig. 20. Public communication plan

Appropriate infrastructure and capabilities for public communication, both on-site and off-site, including human resources and financial resources, should be allocated. Such infrastructure and capabilities should be sufficient for ensuring effective and efficient communication during the emergency response phase and during the transition phase.

Those responsible for public communication in an emergency should anticipate that the need for public communication (and hence the associated infrastructure and resources) during the transition phase will be different from the need for public communication during the emergency response phase.

All resources necessary for public communication during the emergency response phase and during the transition phase should, as far as practicable, be specified, allocated and evaluated at the preparedness stage. This includes the potential long term availability of personnel and of infrastructure and equipment for public communication.

The public communication plan should be reviewed at least once a year and should be revised as necessary at the preparedness stage, taking into account lessons from exercises and from actual emergency responses.

Responsibilities and organizational structure

There may be numerous organizations involved in public communication during a nuclear or radiological emergency: at the facility level, local level, national level, regional level or international level. Arrangements should be made to ensure that the responsibilities for public communication tasks at all levels of the emergency response are specified and understood.

The responsibilities, tasks and coordination of the various organizations that would be involved in public communication during an emergency are required to be planned and specified in advance. The responsibilities, tasks and coordination of the organizations that would be involved in public communication should be reflected in all organizational, local and national emergency plans.

Putting health hazard in perspective

Need to be mentioned the Requirement 4 about Hazard Assessment as mentioned below.

The government shall ensure that a hazard assessment is performed to provide a basis for a graded approach in preparedness and response for a nuclear or radiological emergency.

Hazards shall be identified and potential consequences of an emergency shall be assessed to provide a basis for establishing arrangements for preparedness and response for a nuclear or radiological emergency. These arrangements shall be commensurate with the hazards identified and the potential consequences of an emergency.

For the purposes of these safety requirements, assessed hazards are grouped in accordance with the emergency preparedness categories shown below and establish the basis for a graded approach to the application of these requirements and for developing generically justified and optimized arrangements for preparedness and response for a nuclear or radiological emergency as follows:

I Category Facilities, such as nuclear power plants, for which on-site events, (including those not considered in the design) are postulated that could give rise to severe deterministic effects' off the site that would warrant precautionary urgent protective actions, urgent protective actions or early protective actions, and other response actions to achieve the goals of emergency response in accordance with international standards, or for which such events have occurred in similar facilities.

II Category Facilities, such as some types of research reactor and nuclear reactors used to provide power for the propulsion of vessels (e.g. ships and submarines), for which on-site events, are postulated that could give rise to doses to people off the site that would warrant urgent protective actions or early protective actions and other response actions to achieve the goals of emergency response in accordance with international standards, or for which such events have occurred in similar facilities. Category II (as opposed to category I) does not include facilities for which on-site events (including those not considered in the design) are postulated that could give rise to severe deterministic effects off the site, or for which such events have occurred in similar facilities.

III Category Facilities, such as industrial irradiation facilities or some hospitals, for which on-site events are postulated that could warrant protective actions and other response actions on the site to achieve the goals of emergency response in accordance with international standards, or for which such events have occurred in similar facilities. Category III (as opposed to category II) does not include facilities for which events are postulated that could warrant urgent protective actions or early protective actions off the site, or for which such events have occurred in similar facilities.

IV Category Activities and acts that could give rise to a nuclear or radiological emergency that could warrant protective actions and other response actions to achieve the goals of emergency response in accordance with international standards in an unforeseen location. These activities and acts include: (a) transport of nuclear or radioactive material and other authorized activities involving mobile dangerous sources such as industrial radiography sources, nuclear powered satellites or radioisotope thermoelectric generators; and (b) theft of a dangerous source and use of a radiological dispersal device or radiological exposure device. This category also includes: (i) detection of elevated radiation levels of unknown origin or of commodities with contamination; (ii) identification of clinical symptoms due to exposure to radiation; and (iii) a transnational emergency that is not in category V arising from a nuclear or radiological emergency in another State. Category IV represents a level of hazard that applies for all States and jurisdictions.

V Category Areas within emergency planning zones and emergency planning distances in a State for a facility in category I or II located in another State.

The government shall ensure that for facilities and activities, a hazard assessment on the basis of a graded approach is performed. The hazard assessment shall include consideration of:

(a) Events that could affect the facility or activity, including events of very low probability and events not considered in the design;

(b) Events involving a combination of a nuclear or radiological emergency with a conventional emergency such as an emergency following an earthquake, a volcanic eruption, a tropical cyclone, severe weather, a tsunami, an aircraft crash or civil disturbances that could affect wide areas and/or could impair capabilities to provide support in the emergency response;

(c) Events that could affect several facilities and activities concurrently, as well as consideration of the interactions between the facilities and activities affected;

(d) Events at facilities in other States or events involving activities in other States.

The government shall ensure that the hazard assessment identifies those facilities and locations at which there is a significant likelihood of encountering a dangerous source that is not under control.

The government shall ensure that the hazard assessment includes consideration of the results of threat assessments made for nuclear security purposes.

In the hazard assessment, facilities and activities, on-site areas, off-site areas and locations shall be identified for which a nuclear or radiological emergency could — with account taken of the uncertainties in and limitations of the information available — warrant any of the following:

(a) Precautionary urgent protective actions to avoid or to minimize severe deterministic effects by keeping doses below levels approaching the generic criteria at which urgent protective actions and other response actions are required to be undertaken under any circumstances;

(b) Urgent protective actions and other response actions to avoid or to minimize severe deterministic effects and to reduce the risk of stochastic effects;

(c) Early protective actions and other response actions;

(d) Other emergency response actions such as longer term medical actions, and emergency response actions aimed at enabling the termination of the emergency;

(e) Protection of emergency workers.

The government shall ensure that the hazard assessment also identifies non-radiation-related hazards to people on the site and off the site that are associated with the facility or activity and that may impair the effectiveness of the response actions to be taken.

The government shall ensure that a review of the hazard assessment is performed periodically with the aims of:

(a) ensuring that all facilities and activities, on-site areas, off-site areas and locations where events could occur that would necessitate protective actions and other response actions are identified, and

(b) taking into account any changes in the hazards within the State and beyond its borders, any changes in assessments of threats for nuclear security purposes, the experience and lessons from research, operation and emergency exercises, and technological developments. The results of this review shall be used to revise the emergency arrangements as necessary.

The government through the regulatory body shall ensure that operating organizations review appropriately and, as necessary, revise the emergency arrangements:

(a) prior to any changes in the facility or activity that affect the existing hazard assessment and (b) when new information becomes available that provides insights into the adequacy of the existing arrangements.

Putting health hazard in perspective

In a nuclear or radiological emergency, the response organizations should expect to receive questions from the public and the news media on potential adverse consequences for human life, health, property and the environment. This has been demonstrated by experience from the response to past emergencies.

The Fukushima Daiichi Accident: Report by the Director General states:

“Factual information on radiation effects needs to be communicated in an understandable and timely manner to individuals in affected areas in order to enhance their understanding of protection strategies, to alleviate their concerns and support their own protection initiatives.”

Paragraph 5.72 of GSR Part 7 states:

“The government shall ensure that a system for putting radiological health hazards in perspective in a nuclear or radiological emergency is developed and implemented with the following aim:

- To support informed decision making concerning protective actions and other response actions to be taken;
- To help in ensuring that actions taken do more good than harm;
- To address public concerns regarding potential health effects.”

The 2012 Report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) distinguishes between the following:

a) Health effects that are demonstrable and therefore can be attributed14 to radiation exposure;

b) Radiation risks, or possibilities of harm, usually associated with radiation exposure, which could only be inferred in possible or future exposure situations and are used mainly for radiation protection purposes.

Health effects that are objectively and scientifically attributed to radiation exposure have been considered in the past in parallel with those health effects that are possibly associated with radiation exposure but cannot be demonstrated and for which risks can only be subjectively inferred. This has created communication problems, which have sometimes been detrimental to the people to be protected and have resulted in psychological harm to the people affected.

A number of studies on psychological conditions following the Fukushima Daiichi accident have been performed. According to these studies, communication and dissemination of accurate information to the public at an early stage and during the development of the accident contributed to the alleviation of undesired psychological reactions.

In the context of General Safety Guide No. GSG-14, the term ‘radiological health hazards’ is used in relation to health effects that can be attributed to exposure to radiation. Radiological health hazards in a nuclear or radiological emergency should be explained and put in perspective in a clear, accurate and comprehensible manner. Putting radiological health hazards in perspective is important when explaining clearly to the public and the news media any technical or scientific information in a nuclear or radiological emergency. It is equally important to put such hazards in perspective when addressing the primary public concerns (i.e. 'Am I safe?') in a nuclear or radiological emergency.

The system for putting radiological health hazards in perspective in an emergency should be developed at the preparedness stage for use in public communication at any stage.

The system for putting radiological health hazards in perspective should be developed with the involvement of relevant technical experts as well as professionals in public communication. The system should be developed in consultation with the public and other interested parties.

The concepts underlying the system for putting radiological health hazards in perspective should be sufficiently well understood by those involved in public communication to ensure that these concepts are consistently reflected at any stage. The system should be tested with selected audiences for its suitability and adequacy prior to its adoption.

The system for putting radiological health hazards in perspective should be suitable for use in informing the public and other interested parties of the reasons for complying with instructions on protective actions and other response actions (or, as appropriate, why no specific emergency response actions are necessary).

The system for putting radiological health hazards in perspective should be used to address public concerns about potential radiation induced health

effects. At the preparedness stage (as well as during an emergency response), those responsible for public communication should consider maintaining regular communication with and consultation of the public and other interested parties on concerns about potential radiological health effects. Such communication and consultation are intended at the preparedness stage, as well as during an emergency response, to support the effective implementation of protective actions and other response actions.

The system for putting radiological health hazards in perspective should support effective public protection and should not prevent the implementation of additional measures that are justified and optimized. Thus, such a system should not substitute the need for authorities to further implement monitoring and assessments, medical screenings and diagnosis as well as the need to conduct epidemiological studies, when appropriate, with the aim of making an accurate attribution of radiation induced health effects after a nuclear or radiological emergency. Instead, the system for putting radiological health hazards in perspective is intended to facilitate effective communication when detailed assessments are not yet available.

The following should be considered in developing a system for putting radiological health hazards in perspective:

(a) The rationale for taking protective actions and other response actions in a nuclear or radiological emergency;

(b) Health effects that have been scientifically attributed to exposure to radiation and the association of such health effects with indicators such as estimated doses or measured radiological quantities in an emergency;

(c) Public concerns and the need to respond to them in a clear and comprehensible manner;

(d) The public's perception of radiological health hazards in comparison with that of technical experts.

International Nuclear and Radiological Event Scale (INES)

The International Nuclear and Radiological Event Scale is used for promptly and consistently communicating to the public the safety significance of events associated with sources of radiation. It covers a wide spectrum of practices, including industrial use such as radiography, use of radiation sources in hospitals, activities at nuclear facilities, and the transport of radioactive material. By putting events from all these practices into a proper perspective, use of INES can facilitate a common understanding between the technical community, the media and the public.

MANAGING THE MEDICAL RESPONSE IN A NUCLEAR OR RADIOLOGICAL EMERGENCY

Managing the medical response (general aspects)

An emergency is a non-routine situation that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human health and safety, quality of life, property or the environment. This definition encompasses nuclear and radiological emergencies and conventional emergencies such as fires, release of hazardous chemicals and natural disasters. It includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard. A nuclear or radiological emergency is one in which there is, or is perceived to be, a hazard due to the energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction, or due to radiation exposure.

IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles, Principle 9, states that:

"The primary goals of preparedness and response for a nuclear or radiation emergency are:

- To ensure that arrangements are in place for an effective response at the scene and, as appropriate, at the local, regional, national and international levels, to a nuclear or radiation emergency;
- To ensure that, for reasonably foreseeable incidents, radiation risks would be minor;
- For any incidents that do occur, to take practical measures to mitigate any consequences for human life and health and the environment."

Requirement 12 GSR Part 7 states:

- The government shall ensure that arrangements are in place for the provision of appropriate medical screening and triage, medical treatment and longer term medical actions for those people who could be affected in a nuclear or radiological emergency.
- On the presentation by an individual of clinical symptoms of radiation exposure or other indications associated with a possible nuclear or radiological emergency, the medical personnel or other responsible parties who identify the clinical symptoms or other indications shall notify the appropriate local or national officials and shall take response actions as appropriate.
- Arrangements shall be made for medical personnel, both general practitioners and emergency medical staff, to be made aware of the clinical symptoms of radiation exposure, and of the appropriate notification procedures and other emergency response actions to be taken if a nuclear or radiological emergency arises or is suspected.
- Arrangements shall be made so that, in a nuclear or radiological emergency, individuals with possible contamination can promptly be given appropriate medical attention. These arrangements shall include ensuring that transport services are provided where needed and providing instructions to medical personnel on the precautions to take.
- For facilities in categories I, II and III, arrangements shall be made to manage an adequate number of any individuals with contamination or of any individuals who have been overexposed to radiation, including arrangements for first aid, the estimation of doses, medical transport and initial medical treatment in predesignated medical facilities.
- For areas within emergency planning zones, arrangements shall be made for performing medical screening and triage and for assigning to a predesignated medical facility any individual exposed at levels exceeding the established criteria. These arrangements shall include the use of pre-established operational criteria in accordance with the protection strategy.

- Arrangements shall be made to identify individuals with possible contamination and individuals who have possibly been sufficiently exposed for radiation induced health effects to result, and to provide them with appropriate medical attention, including longer term medical follow-up. These arrangements shall include:
  a) Guidelines for effective diagnosis and treatment;
  b) Designation of medical personnel trained in clinical management of radiation injuries;
  c) Designation of institutions for evaluating radiation exposure (external and internal), for providing specialized medical treatment and for longer term medical actions.
- These arrangements shall also include the use of pre-established operational criteria in accordance with the protection strategy and arrangements for medical consultation on treatment following any exposure that could result in severe deterministic effects with medical personnel experienced in dealing with such injuries.

Arrangements shall be made for the identification of individuals who are in those population groups that are at risk of sustaining increases in the incidence of cancers as a result of radiation exposure in a nuclear or radiological emergency. Arrangements shall be made to take longer term medical actions to detect radiation induced health effects among such population groups in time to allow for their effective treatment. These arrangements shall include the use of pre-established operational criteria in accordance with the protection strategy.

During a radiation emergency, radiation workers, first responders or the public in general may be subjected to external irradiation, to internal/external contamination with radionuclides or to both conditions, which may be combined with conventional injuries such as trauma. External irradiation (or external exposure) may originate from a radiation source, or, in the eventuality of a nuclear accident (as at the Chernobyl and Fukushima Daiichi nuclear power plants), from airborne radionuclides (cloud shine), radionuclides deposited on clothing and skin or radionuclides deposited on the ground (ground shine). Internal contamination may originate from inhalation or ingestion of radionuclides or from radioactive material deposited on wounds, and, exceptionally, from absorption through the intact skin.

The IAEA has issued a number of publications on planning and preparedness for and overall response to radiation emergencies, which cover a wide spectrum of emergency scenarios as well as the respective medical interventions.

Radiation emergencies may involve, for example, the following facilities, activities or applications:

- Irradiation facilities (sterilization of food and medical supplies);
- Nuclear reactors (power generation and research);
- Radioisotope production facilities;
- Industrial radiography facilities (or industrial radiography on other sites);
- X ray and radiotherapy (medicine, research);
- Unsealed radionuclides (medicine, research);
- Transport of radioactive materials;
- Malicious acts involving radioactive materials.
- Independently of its application, in general terms, any activity with open radioactive sources implies a risk of internal contamination with radionuclides.

Managing the medical response to a nuclear or radiological emergency at the scene and transportation

In radiation emergencies, the first priorities at the scene are conventional medical evaluation and the stabilization of patients. Internal contamination by itself does not cause immediate acute manifestations or life threatening health conditions.

An appropriate response to a radiation emergency will reduce the risk of internal contamination and external exposure for individuals in general (the public) as well as for responders.
Detailed information for planning and delivering the generic and first response to a radiation emergency may found in various publications issued by the IAEA, the World Health Organization (WHO) and other international organizations.

To be completed by: Radiological Assessor	**WORKSHEET C1** **VICTIM CONTAMINATION CONTROL RECORD (ON-SCENE ASSESSMENT)**	*No.* ______

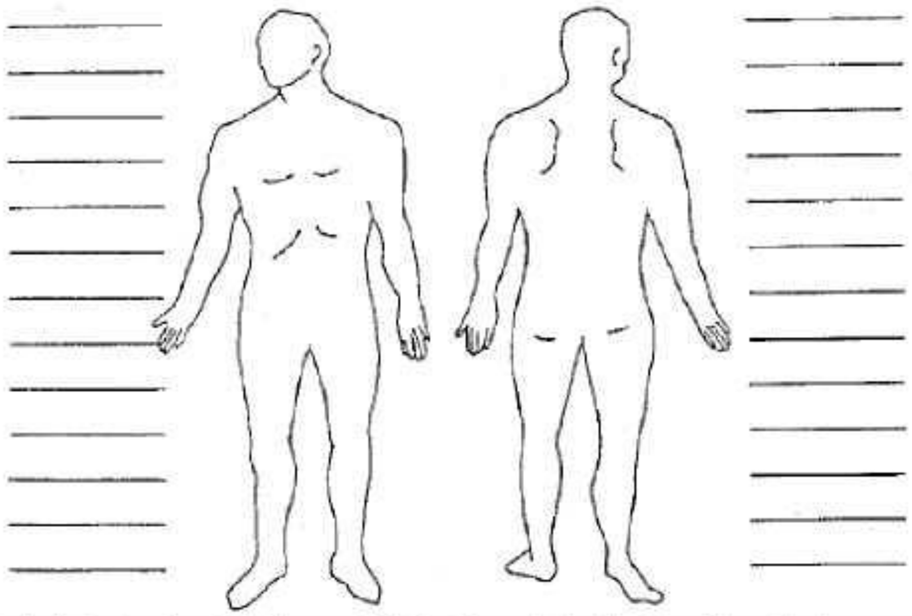
Surveyed by: ______________________ (Full name) Date: __________

Provide to: ☐ Emergency Medical Responder Time: __________

Name of victim: ______________________ Sex: ☐ M ☐ F
Address: ______________________
Date of measurement: _____/_____/_____ Time of measurement: __________

Contamination survey

Instrument type: ______________ Model: __________
Background reading: ____________ Detector active surface: __________ [cm^2]



Remarks: Indicate readings in the lines provided in the diagram. Indicate location of the readings by arrows. Only record readings greater than background.

Decontamination procedures performed: ☐ Yes ☐ No
Results of thyroid survey: ____________ [ ] (count rate from neck) [Unit] ____________ [ ] (count rate from thigh) [Unit]
____________ [ ] (background count rate) [Unit] ____________ [ ] (net count rate) [Unit]
Calibration coefficient: ________ [Bq/Unit of count rate] Activity_____ [Bq]
Further evaluation at medical facility necessary: ☐ Yes ☐ No
Surveyor signature: ______________

Fig. 21. Sample of a worksheet for radioactive contamination control of a person involved in a radiation emergency

Goals of emergency medical response:

1. Save lives and perform required emergency medical procedures;
2. Treat radiation injuries and injuries resulting from an emergency situation;
3. Perform required public health actions, including public advice and counseling, and long term medical follow-up.

In general terms, the main objectives of the on-site medical response include:

- Triage of victims: identification of individuals with life-threating conditions, medical stabilization for as long as necessary (or possible) and transfer to emergency medical care facilities;
- Identification and assistance of other individuals with non-life-threating injuries;
- Identification of those who may be externally and/or internally contaminated and prevention of the spread of contamination.

Radiological contamination can be either external (clothes, skin) or internal (presence of radionuclides inside the body), or both. External contamination is out of the primary scope of this manual and will not be covered in detail. However, external and internal contaminations are inherently related, and, from the medical perspective, some concepts can be applied to both circumstances.

Decontamination efforts at the scene will normally be limited to the removal of external clothes and shoes and the protection of body areas and wounds suspected to be contaminated. With a few limited exceptions, no other decontamination procedures are advisable or feasible on the scene of a radiation emergency.

Internal contamination with radionuclides does not by itself cause early clinical signs and symptoms. If these occur, two situations need to be considered:

- Association of the radioactive material with a chemical that is responsible for the manifestations, in accordance with its characteristic toxicity.
- The very rare event of a massive internal burden (as happened in the Goiania accident with caesium-137, or a case of internal contamination with a very radiotoxic nuclide such as polonium-210, when acute radiation syndrome (ARS) may develop within days. In such an instance, the clinical and laboratory findings would be pertinent to the diagnosis of ARS.

Therefore, in practical terms, no clinical manifestations are caused by internal contamination with radionuclides. Nevertheless, it is worth mentioning that, once an individual is aware that he or she is ‘contaminated with a radioactive material’, he or she can present unspecific manifestations such as nausea and vomiting of psychological aetiology, which are not to be taken unequivocally as prodromal manifestations of ARS.

The main health concern with internal contamination with radionuclides is the stochastic late effect of cancer development. The probability for this development depends on a number of factors, such as the radiotoxicity of the contaminant, route of entry, radiosensitivity of the target organ or tissue, and age of the person at the time of the contamination. The International Commission on Radiological Protection (ICRP) and other organizations have derived nominal dose coefficients for cancer risk development.

Any emergency personnel who notice signs or symbols indicating radiation hazard in areas where an injured person is located have to be aware of the possibility of contamination or exposure and act in accordance with these potential conditions. The first priority at the scene of a radiation emergency is the medical evaluation and stabilization of victims, as already outlined. In many instances, removal of external clothes will not jeopardize the medical evaluation and consequent stabilization. It is important that the transport of seriously injured victims not be delayed because of radiological monitoring or decontamination efforts.

Wounds will need to be protected with impermeable dressing to avoid contamination or intake of radionuclides if contamination is actually present. It is not advisable to attempt to decontaminate the wounds at the scene.

It will need to be assumed that those patients who have been considered as externally contaminated could be also internally contaminated.

Transportation of patients contaminated with radioactive materials from the emergency scene to the hospital will follow pre-established radiation protection protocols, as long as this does not cause any delay in the medical assistance of individuals with life threatening conditions.

All materials that were used to handle and treat the patient or that may have come in contact with the patient during transport, including gloves, pads, bandages, splints, oxygen masks, blood pressure cuffs etc., and any waste remaining in the ambulance will need to be considered contaminated.

When dispersion of radioactive material (dust/smoke/liquid) is suspected or confirmed, the victim(s) will need to be removed from the contaminated scene as soon as possible to avoid or minimize intake of radioactive materials to the body by inhalation or ingestion.

Normally, first responders are protected against radiological contamination by standard biosafety procedures. The use of respiratory protective equipment may be indicated in special conditions in which air dispersion of radioactive material is or could be present and in case of fire and smoke.

As a basic safety measure, members of the medical transport team will not eat, drink or smoke at the emergency scene, in the transport vehicle or at the hospital facilities, until they have been surveyed and released by the appropriate service of the hospital (Radiation Protection Support Group).

Unstable patients have priority for medical evaluation, and the stabilization of the patient should occur before any decontamination or dosimetric procedure is attempted

After medical triage, if there is no need for urgent removal to the hospital, contamination monitoring may be performed by qualified personnel on the scene or in a reception centre on victims with no serious or life threatening conditions or on those that have already been stabilized. In the following situations, it is possible that victims incurred internal contamination, and confirmatory evaluation is needed:

- In a radiation emergency with dispersion of radioactive material (dust, smoke, liquid);
- If contamination is detected, especially on the head, hair, face or hands.

Measuring and identifying radionuclides at the scene is not normally possible, nor is it strictly necessary from the medical point of view. Therefore, if victims or patients are potentially internally contaminated, they need to be transferred to a hospital or facility where measuring and identification of radionuclides can be performed by in vivo counting (whole body counting, thyroid counting, lung counting) and/or by in vitro analyses (faeces and urine bioassays).

Decorporation treatment is not recommended at the scene of a radiation emergency; transport of injured victims is not to be delayed because of decontamination procedures. Non-specific decorporation measures, such as gastric lavage, could be indicated in some special conditions as an early initial countermeasure for internal contamination with radionuclides, but contraindications and complications that might occur during this procedure have to be taken into account. Complications associated with gastric lavage have been well described in the medical literature, and they include aspiration pneumonia, laryngospasm, arrhythmia, oesophageal or stomach perforation, fluid and electrolyte imbalance, and small conjunctival haemorrhages. Therefore, this or similar measures should not be considered for management on the scene.

General considerations in the medical management of internal contamination

During a radiation emergency, workers, first responders and members of the public may become internally contaminated with radionuclides. The possible shortage of medical resources, such as personnel and facilities, the lack of therapeutic strategies and the insufficiency of countermeasures to avoid or minimize radiation exposure may compromise the overall response. Careful planning and allocation of medical resources are essential for an efficient response that addresses the possible health consequences of a radiation emergency. In this respect, radiation contamination poses logistical and technical challenges.

In radiation emergencies, as in other emergency situations, individuals may arrive at hospitals by self-referral and hospitals need to be prepared to receive people with little or no warning and to enact planned measures to protect personnel, conventional hospital patients, visitors, volunteers, facilities and equipment from radiation contamination. In addition, essential procedures need to be available in order to avoid disruption of ordinary activities.

As part of planning and preparedness, the risks associated with treating patients with internal radiation contamination need to be well communicated to health personnel in hospitals, especially to those who have little knowledge of radiation or limited experience in treating patients with radiation exposure or contamination. It is important to emphasize that, in most cases, universal biosafety precautions are adequate for the safe handling of patients contaminated with radionuclides.

Hospitals in general, and especially those within a system designed to respond to radiation emergencies, need their personnel to be well informed of the actual risks related to assisting patients contaminated with radionuclides, and a hospital plan has to be established and periodically updated for proper management. Periodical and systematic drills involving all health personnel (including medical doctors, nurses, technicians and other professionals) that could take part in the medical response to a radiation emergency are paramount in order to: (a) avoid an exaggerated perception of the risks and (b) instill good practices, including those of radiation protection.

Specific decorporating drugs need to be available, and the stockpile has to be kept under strict control by the appropriate national and local public health authorities. It is important that medical protocols for the management of internal contamination with radionuclides be available and periodically updated.

A fundamental conceptual aspect that will be mentioned frequently in this manual is that treatment of any concomitant life threatening condition always takes precedence over radiological assessment and external or internal radiological decontamination.

Children, pregnant women, the elderly, people on continuous medication, people with physical or mental disabilities and minority cultural or linguistic groups are considered populations that need special attention in emergencies, including radiation emergencies. For each group, special considerations may be necessary and need to be considered in the planning of the medical response.

Managing the medical response to a nuclear or radiological emergency at the hospital

The most important factor to be analysed and taken into immediate consideration is the health status of the patient. The management of life threatening conditions needs to have absolute priority and be handled under traditional medical and surgical protocols. Dose estimations, decontamination procedures and decorporation therapy are secondary priorities in these cases. Therefore, initially, hospital emergency personnel have to triage individuals by using conventional medical and trauma criteria.

There are no specific clinical manifestations caused by internal contamination with radionuclides as such, unless a toxic chemical agent is associated.

No matter how internally or externally contaminated an unstable patient may be, this will never be a significant health risk for the medical personnel and staff in charge, as long as standard biosafety and basic radiation protection precautions are adopted. Unless absolutely necessary, female personnel with confirmed or possible pregnancy should avoid working directly in contact with patients contaminated with radionuclides, even though the occupational risk for accidental incorporation would be minimal.

By way of comparison, the radiological risk to health care personnel assisting such a patient is similar to or lower than the biological hazard from normal medical practice.

Depending on the condition of the patient, when contamination has been detected in areas not covered by clothing, washing those parts of the body, especially the hands, head and neck, under running water reduces the risk of accidental intake (in stable patients). Initial nasal, oral and/or wound swabs can be considered before the washing.

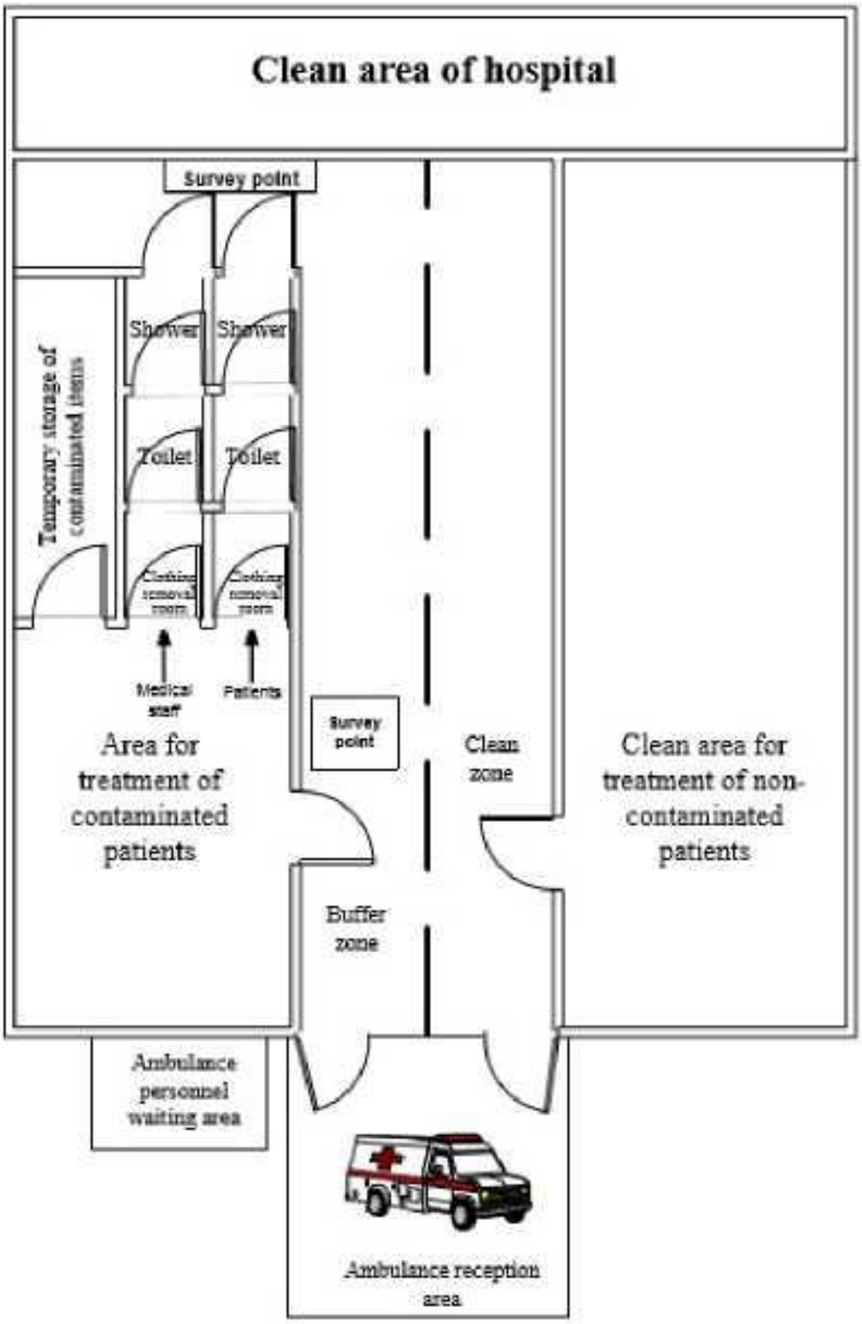


Fig. 22. Sample hospital entrance set-up

To be completed by: Dosimetry Team	**WORKSHEET D1** **RECORD OF PATIENT RADIOLOGICAL SURVEY (AT HOSPITAL)**	*No.* ______

Surveyed by: ______________________________ Date: ___________
(Full name)

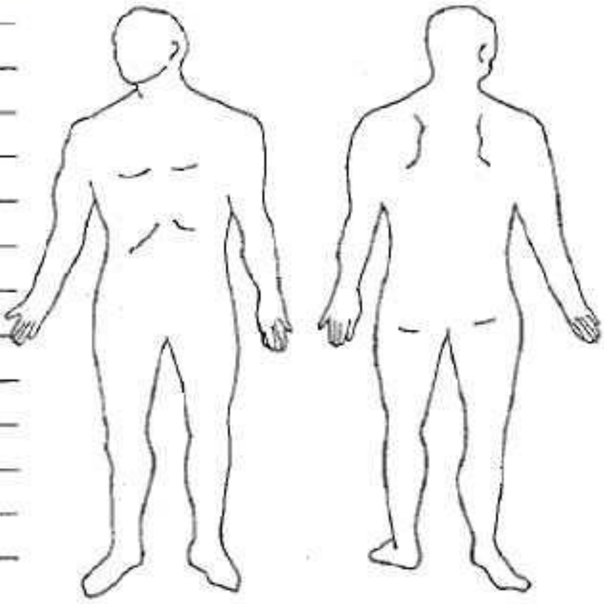
Provide to: ☐ Hospital Emergency Department Response Team
☐ Health/Medical Physicist Time: ___________

Performed in: ☐ Hospital ambulance reception area
☐ Hospital treatment area

Name of victim: ______________________________ Sex: ☐ M ☐ F
Date of measurement: _____/_____/_____ Time of measurement: ___________

Contamination survey

Instrument type: __________________ Model: ___________
Background reading: ______________ Detector active surface: _____________ [cm²]



Remarks: Indicate readings in the lines provided in the diagram. Indicate location of the readings by arrows. Only record readings greater than background.

Results of thyroid survey: _________________ [ ] _________________ [ ]
(count rate from neck) [Unit] (count rate from thigh) [Unit]
_________________ [ ] _________________ [ ]
(background count rate) [Unit] (net count rate) [Unit]
Calibration coefficient: _________ [Bq/Unit of count rate] Activity_____ [Bq]

Further evaluation at medical facility necessary: ☐ Yes ☐ No
Surveyor signature: _________________

Fig. 23. Sample of a worksheet for recording radioactive contamination surveys of a person involved in a radiation emergency

The hospital management of patients involved in radiation emergencies includes:

- Evaluation of patients for evidence of ARS and initiation of treatment as necessary;
- Evaluation for emergency treatment of patients with local radiation injuries (such as cutaneous radiation syndrome), contaminated wounds and radionuclide intakes;
- Confirmation (or non-confirmation) of suspected intakes;
- Evaluation and treatment of patients with injuries and psychological distress.

Once the medical condition of the patient(s) is stable, and internal and/or external contamination is suspected, the following actions are considered good practice:

- To restrict access to the treatment area.
- To survey the treatment area to determine the ‘background’ radiation level present, prior to the patient’s arrival (a Geiger-Muller detector from nuclear medicine department could be useful).
- To adhere to the radiation protection standards and procedures, including the use of protective clothing to diminish the risk of contamination, and ideally to assist patients in the designated area of the emergency department in order not to disrupt the routine of the hospital.
- To have a quick head-to-toe radiological survey performed by a radiation protection officer (or by another trained professional) with the appropriate equipment, including a judicious survey of wounds. The wounds may be counted with a Geiger-Muller detector, and the count rate may be used to estimate the intake initially (based on the activity in the wound). This will normally provide sufficient evidence of the presence or absence of gross contamination.
- To remove the patient’s clothes very carefully (if this was not done previously), and place them in plastic bags adequately labelled with the patient’s name and the day and hour of the procedure. Clothes are excellent samples for the identification of the contaminant radionuclides if radiological analysis is available. This procedure could be performed by other organizations in the country; close collaboration with the national competent authority is necessary.
- To notify the national competent authority, if this was not done previously.

If the clinical condition of the patient has been stabilized, the next priority is to treat wounds that might be contaminated. Wound dressings are removed and saved for further evaluation. After irrigating the wound gently with sterile saline, adequate monitoring equipment with a suitable probe can be used to evaluate the effectiveness of the decontamination process. The intact skin immediately adjacent to the wound has to be careful and quickly decontaminated, and drapes applied in the area to prevent the spread of radioactive materials. Irrigation and decontamination of wounds may be optimized by using a tepid saline or water jet under mild pressure.

It is estimated that removing external clothing reduces external contamination (if present) by about 80 to 90 %.

In stable individuals with no wounds, the external decontamination will start on the face (if contamination is present) and then move to the other most contaminated areas. The next priority is to decontaminate body orifices. If contamination is found around the nose or mouth, or if high concentrations of airborne radioactive material are known or suspected to have occurred, there is the potential for internal deposition, and samples (swabs) can be collected.

Biological samples, depending on the condition of the patient, could also be obtained at this stage. Urine and faeces are most commonly used for the estimation of intakes, but breath, blood or other samples are used in special cases. The choice of bioassay sample will depend not only on the major route of excretion, as determined from the physicochemical form of the intake and the biokinetic model for the element(s) involved, but also on such factors as ease of collection, analysis and interpretation. Some of the biological samples that could be obtained are the following:

- Nasal (from each nostril separately) and oral swabs: These could initially be counted with handheld instrumentation to provide limited results that, when positive, might help in the early medical management. In case of negative results, internal contamination may not be excluded, and samples will be sent for further radiological measurements.

- Urine samples: Following the entry of radionuclides into the blood and systemic circulation, clearance from the body will generally be via the urine. Urine contains waste and other materials, including water, extracted by the kidneys from the blood, and collected for up to several hours or more in the bladder before voiding. Because of this mixing in the bladder, radionuclide levels in samples of urine obtained soon after an acute intake need to be interpreted with caution. The bladder will normally be cleared soon after the intake. All samples will need to be analysed. After the first few days, 24-hour samples of urine normally provide the best basis for assessing intake.
- Faecal samples: Intakes of insoluble material can often be assessed by this kind of sample. The mass and composition of individual faecal voidings can be quite variable and depend strongly on the diet. For this reason, reliable estimates of daily faecal excretion rates of radioactive materials can usually be based only on total collections over 3-4 days. Single samples will, in most cases, only be used for screening purposes.
- Blood samples: These samples provide the most direct means for estimating levels of radionuclides present in the systemic circulation, but they are not often used because of medical constraints on the sampling process. With only a few exceptions (e.g. iron-59 and chromium-51 in labelled erythrocytes), blood samples provide very limited information on the total systemic activity following an intake owing to the rapid clearance from the bloodstream and deposition in tissues.
- Tissue samples: For localized deposits of radionuclides with high radiotoxicity (e.g. transuranic elements) in a wound, it is usually advisable, subject to medical advice, to excise the contamination soon after the intake.
- Other biological samples, such as hair and teeth: These can be used to assess intakes, although, in general, they cannot be used for quantitative dose assessments. Tissue samples taken at autopsy may also be used to assess the body content of radionuclides.

Urine, faeces and other biological samples need be collected in uncontaminated areas, in order to ensure that activity measured in the sample is representative of body clearance. Special care needs to be taken in the handling of samples to be used for the assessment of internal exposure. With respect to the potential hazard from contamination, both biological and radioactive contaminants need to be considered.

Many large hospitals have nuclear medicine departments that employ physicians and technical personnel who are trained in the use of radiation detection and measurement instruments. At other hospitals, radiology departments may have trained staff who could also assist. It is important to define a clear process for notifying the national authorities, who can provide assessment and support to the medical teams.

Initial decisions for the treatment of patients

The vast majority of radiation emergencies do not involve potentially hazardous levels of external radiation exposure or radionuclide intake. Considering only internal contamination, the route of intake plays an important role in the severity of the expected outcome and in treatment decisions.

The diagnosis of internal contamination may be just presumptive, based on the emergency circumstances and/or preliminary measurement results. A whole body counter is not normally useful for the measurement of accidental contamination, because it is set up and calibrated at a very low level of detection for the occupational monitoring of radiation workers. In addition, there are limited whole body counter facilities.

Bioanalyses for the identification and quantification of radionuclides in the body (urine, faeces and blood samples) are time consuming (24 to 48 h), so there might be instances when the physician needs to decide whether or not to begin treatment exclusively on the basis of presumptive evidence. The following aspects are helpful in making the clinical judgement as to whether or not to initiate treatment even without the confirmatory test results being available:

- History of the accident, including time of occurrence, radionuclide(s) involved (if the information is available), circumstances and results of the dose estimations;
- Probable pathways of contamination (especially through wounds);
- Solubility of the contaminant radioactive material (if known);
- Radiotoxicity of the contaminant (if known);
- Patient's age and his/her specific clinical conditions (pregnancy, liver function, kidney function);
- Toxicity of the drug to be used for decorporation.

Initial analyses from the nasal or oral swabs and wound counts will also help to guide the medical decision, particularly when the samples are taken during the first hour of the accident. They could be also useful to the internal dosimetry laboratory in deciding what amount and type of bioassay sampling may be advisable in order to obtain sufficient data for a better subsequent dose assessment.

Appropriate specialized treatment should be given to any person who receives a radiation dose that could potentially result in severe deterministic health effects. At a given level of intake, some individuals may not need any kind of treatment, while others, depending on multiple factors, could be subject to significant health risks and require pharmacological or other treatments. Since no treatment is completely free of risk, a benefit-to-risk decision has to be made before initiating any course of treatment. It also needs to be taken into account that, for individuals with significant internal intakes, prompt actions are most effective.

When a wound is contaminated and the radionuclide is not removed, the radionuclide may be absorbed and metabolized into the body. Therefore, copious irrigation with physiological saline solution or with diethylenetriamine-pentaacetate (DTPA) (depending on the case) is indicated. Depending on the radionuclide involved in the contamination of a wound, a systemic therapy will need to be considered; for example, for contamination with plutonium or other actinides, treatment with chelation therapy (DTPA) is indicated.

When nasal or oral swabs indicate the inhalation of radionuclides, additional studies may be required to determine the intake and the need for decorporation treatment. However, some situations, such as intake of plutonium or americium, may require the prompt administration of DTPA before a substantial deposition in organs can occur.

In the case of ingestion of radionuclides, there will be a transit time through the gastrointestinal (GI) tract prior to absorption (uptake) into the bloodstream. Some actions, such as the administration of alginates and aluminium-containing compounds, can reduce the amount of radionuclides absorbed. These drugs bind some chemical elements (such as strontium), reducing their uptake.

Lessons learned from accidents indicate that the psychological impact of the treatment of radiation induced injuries needs to be minimized. Therefore, the treatment is provided as close to the individual's home as possible, or in a region where the patient's language and culture are common. Provisions for family members to accompany the patient have to be evaluated when treatment is offered in another country.

Each case needs to be analysed by itself by the healthcare and health physics teams. The patient will be fully briefed on the risks and benefits associated with the treatment method.

Advanced medical care, including medical specialists who manage the care for severely exposed or internally contaminated patients should be provided in specialized medical clinics, hospitals, etc.

MANAGING RADIOACTIVE WASTE

Type of radioactive waste generated in a nuclear or radiological emergency

As states in GSR Part7:

“The government shall ensure that radioactive waste is managed safely and effectively in a nuclear or radiological emergency.

The national policy and strategy for radioactive waste management shall apply for radioactive waste generated in a nuclear or radiological emergency…

The protection strategy shall take into account radioactive waste that might arise from protective actions and other response actions that are to be taken.

Radioactive waste arising in a nuclear or radiological emergency, including radioactive waste arising from associated protective actions and other response actions taken, shall be identified, characterized and categorized in due time and shall be managed in a manner that does not compromise the protection strategy, with account taken of prevailing conditions as these evolve.

Arrangements shall be made for radioactive waste to be managed safely and effectively. These arrangements shall include:

a) A plan to characterize waste, including in situ measurements and analysis of samples;

b) Criteria for categorization of waste;

c) Avoiding, to the extent possible, the mixing of waste of different categories;

d) Minimizing the amount of material unduly declared as radioactive waste;

e) A method for determining appropriate options for predisposal management of radioactive waste (including processing, storage and transport), with account taken of the interdependences between all steps as well as impacts on the anticipated end points (clearance, authorized discharge, reuse, recycling, disposal);

f) A method of identifying appropriate storage options and sites;

g) Consideration of non-radiological aspects of waste (e.g. chemical properties such as toxicity, and biological properties).

Consideration shall be given to the management of human remains and animal remains with contamination as a result of a nuclear or radiological emergency, with due account taken of religious practices and cultural practices.”

A comprehensive range of waste classes has been defined and general boundary conditions between the classes are provided. More detailed quantitative boundaries that take into account a broader range of parameters may be developed in accordance with national programmes and requirements. In cases when there is more than one disposal facility in a State, the quantitative boundaries between the classes for different disposal facilities may differ in accordance with scenarios, geological and technical parameters and other parameters that are relevant to the site specific safety assessment.

In general six classes of waste are derived and used as the basis for the classification scheme:

1) ***Exempt waste (EW):*** Waste that meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes.

2) ***Very short lived waste (VSLW):*** Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared from regulatory control according to arrangements approved by the regulatory body, for uncontrolled disposal, use or discharge. This class includes waste containing primarily radionuclides with very short half-lives often used for research and medical purposes.

3) ***Very low level waste (VLLW):*** Waste that does not necessarily meet the criteria of EW, but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities with limited regulatory control. Such landfill type facilities may also contain other hazardous waste. Typical waste in this class includes soil and rubble with low levels of activity concentration. Concentrations of longer lived radionuclides in VLLW are generally very limited.

4) ***Low level waste (LLW):*** Waste that is above clearance levels, but with limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near surface facilities. This class covers a very broad range of waste. LLW may include short lived radionuclides at higher levels of activity concentration, and also long lived radionuclides, but only at relatively low levels of activity concentration.

5) ***Intermediate level waste (ILW):*** Waste that, because of its content, particularly of long lived radionuclides, requires a greater degree of containment and isolation than that provided by near surface disposal. However, ILW needs no provision, or only limited provision, for heat dissipation during its storage and disposal. ILW may contain long lived radionuclides, in particular, alpha emitting radionuclides that will not decay to a level of activity concentration acceptable for near surface disposal during the time for which institutional controls can be relied upon. Therefore, waste in this class requires disposal at greater depths, of the order of tens of metres to a few hundred metres.

6) ***High level waste (HLW):*** Waste with levels of activity concentration high enough to generate significant quantities of heat by the radioactive decay process or waste with large amounts of long lived radionuclides that need to be considered in the design of a disposal facility for such waste. Disposal in deep, stable geological formations usually several hundred metres or more below the surface is the generally recognized option for disposal of HLW.

Quantitative values of allowable activity content for each significant radionuclide will be specified on the basis of safety assessments for individual disposal sites.

Waste classes

A conceptual illustration of the waste classification scheme is presented in Fig. 23. The vertical axis represents the activity content of the waste and the horizontal axis represents the half-lives of the radionuclides contained in the waste. In some cases, the amount of activity, rather than activity concentration, may be used to determine the class of the waste. For example, waste containing only very small amounts of certain radionuclides (e.g. low energy beta emitters) may be excluded or cleared from regulatory control.

Vertically, the level of activity content can range from negligible to very high, that is, very high concentration of radionuclides or very high specific activity. The higher the level of activity content, the greater the need to contain the waste and to isolate it from the biosphere. At the lower range of the vertical axis, below clearance levels, the management of the waste can be carried out without consideration of its radiological properties.

Horizontally, the half-lives of the radionuclides contained in the waste can range from short (seconds) to very long time spans (millions of years). In terms of radioactive waste safety, a radionuclide with a half-life of less than about 30 years is considered to be short lived. It is beneficial to make such a distinction between waste containing mainly short lived radionuclides and waste containing long lived radionuclides because the radiological hazards associated with short lived radionuclides are significantly reduced over a few hundred years by radioactive decay.

A reasonable degree of assurance can be given that institutional control measures to contribute to the safety of near surface disposal facilities for waste containing mainly short lived radionuclides can be kept in place over such time frames.

Limitations placed on the activity (total activity, specific activity or activity concentration) of waste that can be disposed of in a given disposal facility will depend on the radiological, chemical, physical and biological properties of the waste and on the particular radionuclides it contains.

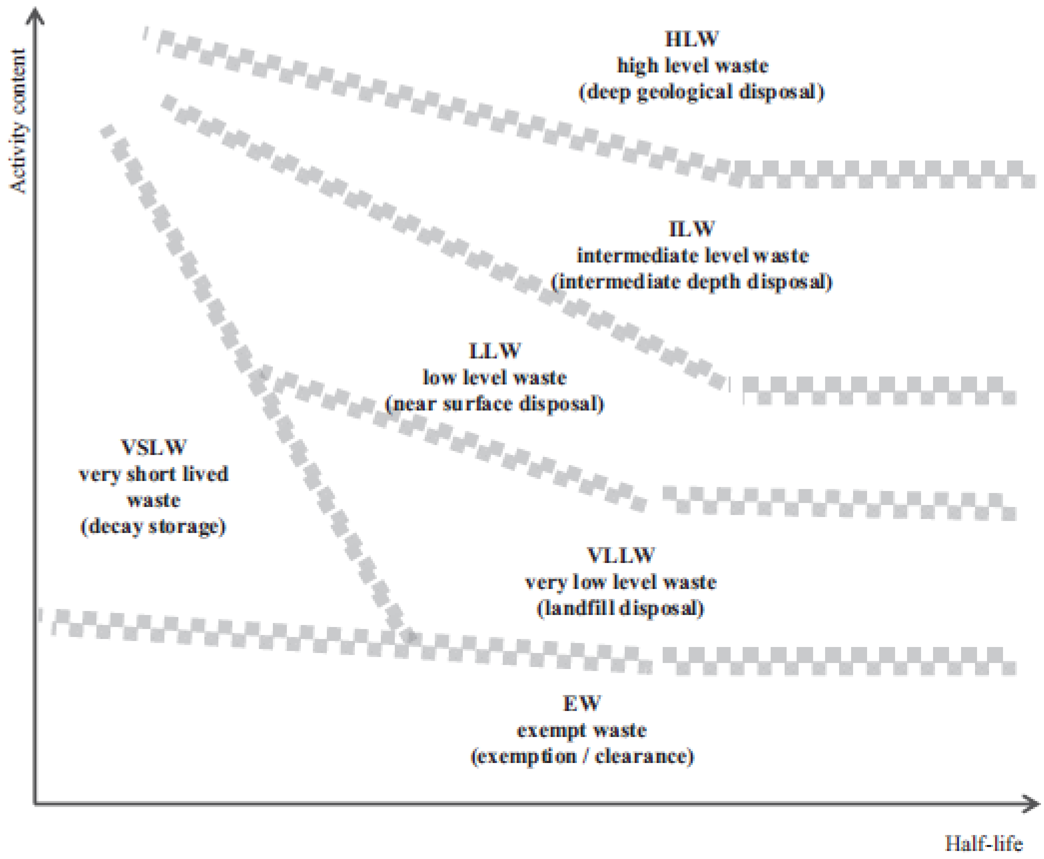


Fig. 23. Waste classification

Exempt waste (EW)

Exempt waste contains such small concentrations of radionuclides that it does not require provisions for radiation protection, irrespective of whether the waste is disposed of in conventional landfills or recycled. Such material can be cleared from regulatory control and does not require any further consideration from a regulatory control perspective.

Liquid or gaseous effluents discharged to the environment under appropriate regulatory control are somewhat analogous to cleared waste, inasmuch as discharged material requires no further consideration from the perspective of radiation protection and safety. There are, however, some notable differences in the establishment of limitations on effluent quantities suitable for discharge and, in the case of discharge of effluents, confirmatory environmental monitoring is normally carried out.

Studies undertaken at the national and international levels have derived radionuclide specific levels of activity concentration for the exemption and clearance of solid material, values of activity concentration for radionuclides of both natural and artificial origin that may be used by the regulatory body for determining when controls over bulk amounts of solid material are not required or are no longer necessary.

The values of activity concentration for artificial radionuclides are derived on the basis of generic scenarios for the recycling and disposal of waste.

For radionuclides of natural origin, a different approach was adopted: these values were determined on the basis of consideration of the upper end of the worldwide distribution of activity concentrations in soil.

Levels of activity concentration for exempt waste may be established by the regulatory body on a case by case basis, providing that consideration is given to specific national circumstances that will significantly influence exposure scenarios, or specific requirements or conditions are defined for the exemption or clearance of waste. Consideration should be given to any possible transboundary implications, if it is conceivable that the material in question might be exported. Levels of activity concentration established by the regulatory body will be highly dependent on the conditions under which exemption or clearance is granted.

Need to be provided a consensus on the boundary for unconditionally exempt or cleared material that may be transferred from one State to another (e.g. for recycling or reuse) without its being subject to regulatory control for the purposes of radiation protection. The existence of such consensus greatly simplifies procedures for exemption and clearance, and it is considered to contribute to an increased level of public confidence in the safety of practices.

Very short lived waste (VSLW)

Very short lived waste contains only radionuclides of very short half-life with activity concentrations above the clearance levels. Such waste can be stored until the activity has fallen beneath the levels for clearance, allowing for the cleared waste to be managed as conventional waste. Examples of very short lived waste are waste from sources using 192Ir and 99mTc and waste containing other radionuclides with short half-lives from industrial and medical applications. Should be noted that storage for decay is frequently used in the management of liquid and gaseous waste containing short half-life radionuclides, which is stored until the activity concentration has fallen beneath the applicable levels for discharge to the environment.

The main criteria for the classification of waste as VSLW are the half-lives of the predominant radionuclides and the acceptability of the amounts of longer half-life radionuclides. Since the intent of storage for decay is to eventually clear the material, acceptable levels of concentration of long half-life radionuclides are set by the clearance levels. The boundary for the half-lives of predominant radionuclides cannot be specified generically because it depends on the planned duration of the storage and the initial activity concentration of the waste. However, in general, the management option of storage for decay is applied for waste containing radionuclides with half-lives of the order of 100 days or less.

The classification of waste as VSLW obviously depends on the point in time at which the waste is assigned a classification. Through radioactive decay, VSLW will move into the class of exempt waste. Thus the classification scheme is not fixed but depends on the actual conditions of the waste in question at the time of assessment. This reflects the flexibility that radioactive decay provides for the management of radioactive waste.

Very low level waste (VLLW)

Substantial amounts of waste arise from the operation and decommissioning of nuclear facilities with levels of activity concentration in the region of or slightly above the levels specified for the clearance of material from regulatory control. Other such waste, containing naturally occurring radionuclides, may originate from the mining or processing of ores and minerals. The management of this waste, in contrast to exempt waste, does require consideration from the perspective of radiation protection and safety, but the extent of the provisions necessary is limited in comparison to the provisions required for waste in the higher classes (LLW, ILW or HLW). Waste with such a limited hazard, which is nevertheless above or close to the levels for exempt waste, is termed very low level waste.

An adequate level of safety for VLLW may be achieved by its disposal in engineered surface landfill type facilities. This is the usual practice for waste from some mining operations and for other waste containing naturally occurring radionuclides from various operations involving minerals processing and other activities. Some States also use this disposal method for waste with low levels of activity concentration arising from nuclear installations. The designs of such disposal facilities range from simple covers to more complex disposal systems and, in general, such disposal systems require active and passive institutional controls. The time period for which institutional controls are exercised will be sufficient to provide confidence that there will be compliance with the safety criteria for disposal of the waste.

In order to determine whether a particular type of waste can be considered to fall into the class of VLLW, acceptance criteria for engineered surface landfill type facilities have to be derived. This can be carried out either using generic scenarios or by undertaking a safety assessment for a specific facility in a manner approved by the regulatory body. The criteria derived will depend on the actual site conditions and on the design of the engineered structures or, in the case of the use of generic scenarios, on assumptions made to take account of these factors. It is expected that with a moderate level of engineering and controls, a landfill facility can safely accommodate waste containing artificial radionuclides with levels of activity concentrations one or two orders of magnitude above the levels for exempt waste, for waste containing short lived radionuclides and with limited total activity. This applies as long as expected doses to the public are within criteria established by the regulatory body. In general, for waste containing naturally occurring radionuclides, acceptable levels of activity concentration will be expected to be lower than those for waste containing artificial radionuclides, in view of the long half-lives of naturally occurring radionuclides. Depending on site factors and the design, it may still be possible to demonstrate the safety of waste with higher levels of activity concentration.

Another management option for some waste falling within this class, such as waste rock from mining operations, may be the authorized use of the material (e.g. for road construction). In this case, criteria can be derived by using approaches similar to the definition of general clearance values.

Low level waste (LLW)

Low level waste is waste that is suitable for near surface disposal. This is a disposal option suitable for waste that contains such an amount of radioactive material that robust containment and isolation for limited periods of time up to a few hundred years are required. This class covers a very wide range of radioactive waste. It ranges from radioactive waste with an activity content level just above that for VLLW, that is, not requiring shielding or particularly robust containment and isolation, to radioactive waste with a level of activity concentration such that shielding and more robust containment and isolation are necessary for periods up to several hundred years.

Because LLW may have a wide range of activity concentrations and may contain a wide range of radionuclides, there are various design options for near surface disposal facilities. These design options may range from simple to more complex engineered facilities, and may involve disposal at varying depths, typically from the surface down to 30 m. They will depend on safety assessments and on national practices, and are subject to approval by the regulatory body.

Low concentrations of long lived radionuclides may be present in LLW. Although the waste may contain high concentrations of short lived radionuclides, significant radioactive decay of these will occur during the period of reliable containment and isolation provided by the site, the engineered barriers and institutional control. Classification of waste as LLW should, therefore, relate to the particular radionuclides in the waste, and account should be taken of the various exposure pathways, such as ingestion (e.g. in the case of long term migration of radionuclides to the accessible biosphere in the post-closure phase of a disposal facility) and inhalation (e.g. in the case of human intrusion into the waste). Thus, radioactive waste suitable for disposal near the surface and at intermediate depths may, in most instances, be differentiated on the basis of the need for controls over time frames for which institutional control can be guaranteed and thus human intrusion into the waste can be prevented. The suitability of a disposal facility for a particular inventory of waste is required to be demonstrated by the safety case for that facility.

In many States it is assumed that institutional controls can be relied upon for a period of up to around 300 years. Under this assumption, bounding values for low level waste in terms of activity concentration levels can be derived by estimating doses to exposed individuals after this period of institutional control. A special situation arises for waste from the mining and processing of uranium and other materials containing significant amounts of radionuclides of natural origin, for which the activity content will not decrease significantly over such timescales. Since the management of such waste in near surface facilities is in many cases the only practicable option, longer periods of institutional control have to be postulated, with periodic safety review of the facility.

A precise boundary between LLW and intermediate level waste (ILW) cannot be provided, as limits on the acceptable level of activity concentration will differ between individual radionuclides or groups of radionuclides. Waste acceptance criteria for a particular near surface disposal facility will be dependent on the actual design of and planning for the facility (e.g. engineered barriers, duration of institutional control, site specific factors). Restrictions on levels of activity concentration for long lived radionuclides in individual waste packages may be complemented by restrictions on average levels of activity concentration or by simple operational techniques such as emplacement of waste packages with higher levels of activity concentration at selected locations within the disposal facility. It may be possible for a regulatory body to provide bounding levels of activity concentration for LLW on the basis of generic site characteristics and generic facility designs, as well as specified institutional control periods and dose limits to individuals.

The regulatory body should establish limits for the disposal of long lived radionuclides on the basis of the safety assessment for the particular disposal facility. A limit of 400 Bq/g on average (and up to 4000 Bq/g for individual packages) for long lived alpha emitting radionuclides has been adopted in some States. For long lived beta and/or gamma emitting radionuclides, such as 14C, 36Cl, 63Ni, 93Zr, 94Nb, 99Tc and 129I, the allowable average activity concentrations may be considerably higher (up to tens of kilobecquerels per gram) and may be specific to the site and disposal facility.

Intermediate level waste (ILW)

Intermediate level waste is defined as waste that contains long lived radionuclides in quantities that need a greater degree of containment and isolation from the biosphere than is provided by near surface disposal. Disposal in a facility at a depth of between a few tens and a few hundreds of metres is indicated for ILW. Disposal at such depths has the potential to provide a long period of isolation from the accessible environment if both the natural barriers and the engineered barriers of the disposal system are selected properly. In particular, there is generally no detrimental effect of erosion at such depths in the short to medium term. Another important advantage of disposal at intermediate depths is that, in comparison to near surface disposal facilities suitable for LLW, the likelihood of inadvertent human intrusion is greatly reduced. Consequently, long term safety for disposal facilities at such intermediate depths will not depend on the application of institutional controls.

The boundary between the LLW class and the ILW class cannot be specified in a general manner with respect to activity concentration levels, because allowable levels will depend on the actual waste disposal facility and its associated safety case and supporting safety assessment. For the purposes of communication pending the establishment of disposal facilities for ILW, the regulatory body may determine that certain waste constitutes LLW or ILW on the basis of generic safety cases.

High level waste (HLW)

High level waste is defined to be waste that contains such large concentrations of both short and long lived radionuclides that, compared to ILW, a greater degree of containment and isolation from the accessible environment is needed to ensure long term safety. Such containment and isolation is usually provided by the integrity and stability of deep geological disposal, with engineered barriers. HLW generates significant quantities of heat from radioactive decay, and normally continues to generate heat for several centuries. Heat dissipation is an important factor that has to be taken into account in the design of geological disposal facilities.

HLW typically has levels of activity concentration8 in the range of104-106 TBq/m3 (e.g. for fresh spent fuel from power reactors, which some States consider radioactive waste). HLW includes conditioned waste arising from the reprocessing of spent fuel together with any other waste requiring a comparable degree of containment and isolation. At the time of disposal, following a few decades of cooling time, waste containing such mixed fission products typically has levels of activity concentration of around 104 TBq/m3. For the purposes of communication pending the establishment of disposal facilities for HLW, national authorities may determine that certain waste constitutes ILW or HLW on the basis of generic safety cases.

Additional considerations

If the classification scheme is used, the specific types and properties of radioactive waste should be taken into account. The precise criteria according to which waste is assigned to a particular waste class will depend on the specific situation in the State in relation to the nature of the waste and the disposal options available or under consideration. One important type of waste that requires specific consideration is disused sealed sources. Another important type of waste that requires specific consideration is waste containing elevated levels of radionuclides of natural origin, in view of the bulk quantities arising and the different regulatory approaches that have been adopted. Annex III GSG-1 provides an overview of important types of radioactive waste and discusses the special considerations necessary when using the classification scheme for these different types of waste. Figure 24 is a logic diagram illustrating the use of the classification scheme to assist in determining disposal options.

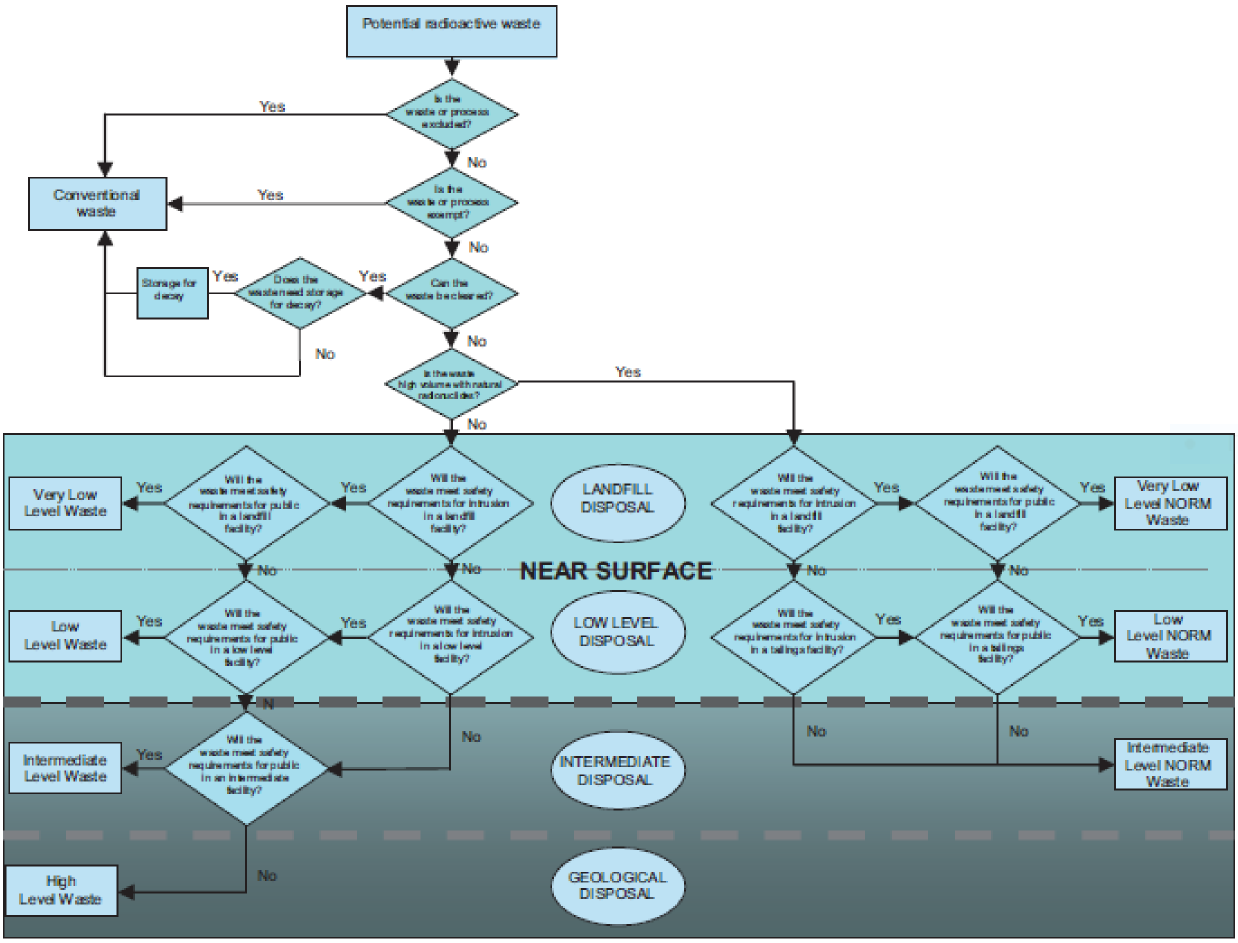


Fig. 24. An illustration of the use of the classification schemes

Although heat generation is a characteristic of HLW, other waste may also generate heat, albeit at lower levels. The amount of heat generated is dependent upon the types and amounts of radionuclides in the waste (e.g. half-life, decay energy, activity concentration and total activity). Furthermore, consideration of heat removal is very important (e.g. thermal conductivity, storage geometry and ventilation). Therefore, the significance of heat generation cannot be defined by means of a single parameter value. The impact of heat generation can vary by several orders of magnitude, depending on the influencing factors and the methods in place for heat removal. Management of decay heat should be considered if the thermal power of waste packages reaches several Watts per cubic metre. More restrictive values may apply, particularly in the case of waste containing long lived radionuclid Fig. 24.

Predisposal and disposal of radioactive waste

Waste containing or contaminated with radionuclides arises from a number of activities involving the use of radioactive materials, such as the operation and decommissioning of nuclear facilities and the application of radionuclides in industry, medicine and research. Radioactive waste is also generated in the cleanup of sites affected by radioactive residues from various operations or from accidents, and can arise in the processing of raw materials containing naturally occurring radionuclides. The nature of this waste is likely to be such that its safe management must take into account radiation safety considerations. In addition to the waste that must be managed and eventually disposed of, some of the materials arising during the aforementioned activities are of value and may be reused or recycled.

Predisposal management of radioactive waste, as the term is used in this Safety Requirements publication, comprises all waste management steps prior to disposal. These include the processing of operational and decommissioning waste as well as that of waste from cleanup activities. The decommissioning of a nuclear facility at the end of its useful lifetime is included in this definition of predisposal waste management. In the sense that decommissioning is the management of nuclear facilities for which no further use is foreseen, it is considered to be a part of radioactive waste management.

In the design of facilities and the planning of activities that have the potential to generate radioactive waste, measures are put in place to avoid or reduce, to the extent practicable, its generation. Waste and other residual materials are appropriately collected or segregated after collection, as necessary. They may be released from regulatory control if they do not require further consideration from the viewpoint of radiation safety. This includes the controlled discharge of effluents produced during predisposal operations. As far as reasonably practicable, the reuse and recycling of materials are applied as means of minimizing waste generation. The remaining waste is processed in accordance with the national strategy for radioactive waste management for storage or disposal.

The principal approaches to the management of radioactive waste are commonly termed ‘delay and decay’, ‘concentrate and contain’ and ‘dilute and disperse’. ‘Delay and decay’ involves holding the waste in storage until the desired reduction in activity has occurred through radioactive decay of the radionuclides contained in the waste. ‘Concentrate and contain’ means reduction of volume and confinement of the radionuclide contents by means of a conditioning process to prevent dispersion in the environment. ‘Dilute and disperse’ means discharging waste to the environment in such a way that environmental conditions and processes ensure that the concentrations of the radionuclides are reduced to such levels that the radiological impact of the released material is acceptable. In establishing policies in this area, consideration has to be given to the radiological impacts of the different management options. From a radiological protection perspective, a balance has to be struck between the present exposures resulting from the dispersal of radionuclides in the environment and potential future exposures which could result as a consequence of radioactive waste disposal.

The first two approaches (‘delay and decay’, ‘concentrate and contain’) require that radioactive waste be held in storage for varying lengths of time or placed in a disposal facility with a view to preventing its release to the environment. Radioactive waste must therefore be processed, as necessary, in such a way that it can be safely placed and held in a storage or disposal facility.

The third approach (‘dilute and disperse’) is a legitimate practice in the management of radioactive waste and has to be carried out within authorized limits established by the regulatory body.

Processing and storage of radioactive waste

Waste processing includes pretreatment, treatment and conditioning of radioactive waste and is intended to produce a waste form compatible with the selected or likely disposal option. Storage may take place between and within the basic steps of radioactive waste management. The conditioned waste must be in a form suitable for handling, transport, storage and disposal.

It may be that not all processing steps are necessary. The type of processing necessary depends on the particular waste, its form and characteristics, and the overall strategy for waste management. Where appropriate, waste or material resulting from processing can be reused or recycled, or released from regulatory control.

Waste is prepared for disposal by means of the aforementioned processing steps. However, in many instances disposal facilities are not available and storage may be necessary for extended periods of time.

In order to select the appropriate type of pretreatment, treatment and conditioning for the radioactive waste when no disposal facility has been established, assumptions have to be made about the likely disposal option. Consideration has then to be given to the potential conflict between the need to contain and store the waste in a passive, safe condition and the desirability of retaining flexibility in waste form so as to avoid prejudicing the choice of eventual disposal options. In striking a balance between closing an option and retaining flexibility, it is necessary to ensure that conflicting requirements that might compromise safety are avoided.

Decommissioning

The term ‘decommissioning’ refers to administrative and technical actions taken to allow the removal of some or all of the regulatory controls from a nuclear facility (except for a repository, for which the term ‘closed’ and not ‘decommissioned’ is used). These actions involve decontamination, dismantling and removal of radioactive materials, waste, components and structures. They are carried out to achieve a progressive and systematic reduction in radiological hazards and are undertaken on the basis of preplanning and assessment, in order to ensure safety during decommissioning operations.

A facility may be considered decommissioned when an approved end state has been reached. Subject to national legal and regulatory requirements, this may encompass situations such as:

- incorporation into a new or existing facility;
- partial or full dismantlement with or without restrictions on further use.

Decommissioning is facilitated if planning and preparatory works are undertaken at the design phase of the nuclear facility and are continued throughout the entire lifetime of the facility.

Protection of human health and the environment

Processes and operations applied in predisposal management of radioactive waste contribute to ensuring that radioactive waste is dealt with in a manner that protects human health and the environment, now and in the future, without imposing undue burdens on future generations.

In considering options in the predisposal management of radioactive waste, due consideration shall be given to the protection of workers and the public and to the protection of the environment. Protection shall also be provided beyond national borders. Such considerations shall include radiological and non-radiological hazards, including conventional health and safety aspects, and the potential impact and burden on future generations from extended periods of storage of radioactive waste or delayed decommissioning of nuclear facilities.

The predisposal management of radioactive waste is part of the entire ‘practice’ giving rise to the waste in the context of the recommendations of the International Commission on Radiological Protection (ICRP) and the IAEA. Radiation protection considerations should therefore be governed by the concepts of justification of a practice, optimization of protection and limitation of doses to individuals. The generation and management of radioactive waste does not need to be justified separately since it should have been taken into account in the justification of the entire practice.

National radiation protection requirements shall be established with due regard for the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No. 115, (BSS). In particular, the radiation protection of any persons who are exposed as a result of activities in predisposal management of radioactive waste shall be optimized, with due regard to dose constraints, and with the exposures of individuals kept within specified dose limits.

The dose limits for normal exposure of workers and members of the public shall be applied as prescribed in national regulations. Internationally endorsed values for these limits are contained in Schedule II of the BSS.

Requirements for environmental protection associated with predisposal management of radioactive waste shall be established by the national regulatory body, taking into consideration all potential environmental impacts that can reasonably be expected.

A ‘safety culture’ shall be fostered and maintained in both the operating organization and the regulatory body in order to encourage a questioning and learning attitude to protection and safety and to discourage complacency. Such a culture is particularly important for decommissioning activities in which new radiological and non-radiological hazards may arise, for example, owing to the removal of safety systems and barriers. This includes the regular audit and review of performance.

Responsibilities associated with predisposal management of radioactive waste, including decommissioning

It is possible that predisposal management of radioactive waste will involve the transfer of the radioactive waste from one operator to another, or that the radioactive waste may even be processed in another country. Similarly, decommissioning may be carried out by an operator different from the operator responsible for facility operation.

Furthermore, decommissioning may be deferred or carried out in a series of discrete operations over time (phased decommissioning). The established legal framework shall contain provisions to ensure that there is clear and unequivocal allocation of responsibility for safety during the entire process of predisposal management of radioactive waste. This continuity of responsibility for safety shall be ensured through regulatory control, e.g. by a licence or a sequence of licences according to the national legal framework.

In the event of the transfer of radioactive waste beyond national boundaries, account shall be taken of the relevant requirements of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. These relate, inter alia, to the need for prior notification and consent of the State of destination, the need for adequate technical and administrative capacity in the State of destination and provisions for movements through transit States.

In the context of decommissioning, the post-operational phase of a nuclear facility, starting with the final shutdown and extending over the entire decommissioning process, shall be regulated, e.g. by a licence, a sequence of licences or other regulatory control, according to the national legal framework.

Regulatory body

To facilitate effective and safe predisposal management of radioactive waste, the regulatory body shall ensure that an appropriate waste classification scheme is established in accordance with national programmes and requirements and international recommendations.

To protect human health and the environment, the regulatory body shall establish requirements and criteria pertaining to the safety of facilities, processes and operations for predisposal management of radioactive waste. These shall include requirements related to handling, transport and storage as well as known or likely requirements associated with the acceptance of waste packages for disposal.

The regulatory body shall establish safety criteria for the decommissioning of nuclear facilities, including conditions on the end points of decommissioning.

The regulatory body shall establish limits and conditions for the removal of controls from materials containing radionuclides. It shall provide guidance for the authorized use of materials and for the authorized discharge of liquids and gases containing radionuclides. The regulatory body shall also consider establishing criteria for the clearance of materials. Such limits, conditions and criteria shall ensure the protection of human health and the environment and shall take account of international recommendations.

The regulatory body shall ensure that relevant documents and records are prepared, kept for an agreed time and maintained to a specified quality. It shall ensure that appropriate parties are responsible for this work.

Operators

Generators of radioactive waste, including organizations carrying out decommissioning activities, and the operators of radioactive waste management facilities are considered to be engaged in predisposal management of radioactive waste. In the context of this Safety Requirements publication, they are hereinafter referred to as ‘operator(s)’.

The operator shall be responsible for all aspects of safety of the facility for predisposal management of radioactive waste during its lifetime and of the decommissioning activity until its completion.

In order to provide an adequate level of safety, the operator shall perform safety and environmental impact assessments; shall prepare and implement appropriate safety procedures; shall apply good engineering practice; shall ensure that staff are trained, qualified and competent; shall establish and implement a quality assurance programme; and shall keep records as required by the regulatory body.

Unless otherwise required by the regulatory body, the operator shall establish and maintain decommissioning plans which are commensurate with the type and status of the facility. The initial decommissioning plan shall be established in the design phase of the facility.

The operator shall establish and maintain emergency planning commensurate with the hazards associated with the predisposal management of radioactive waste and the decommissioning activities, and shall report incidents significant to safety to the regulatory body in a timely manner.

The operator shall identify an acceptable destination for the radioactive waste and shall ensure that radioactive waste is transported safely and in accordance with transport requirements.

The operator may delegate any work associated with the aforementioned responsibilities to other organizations but shall retain overall responsibility and control.

A mechanism for providing adequate financial resources shall be established to cover the costs of radioactive waste management and, in particular, the cost of decommissioning. It shall be put in place before operation and shall be updated, as necessary. Consideration shall also be given to providing the necessary financial resources in the event of premature shutdown of the facility.

At the completion of decommissioning, and before the operator can be relieved of further responsibility for the facility or site in accordance with the national legal framework, the operator shall provide to the regulatory body such information as may be required.

Interdependence

Interdependences among all steps in the generation and management of radioactive waste shall be appropriately taken into account. Owing to the existing interdependences among the various steps in radioactive waste management, all activities from the generation of the waste to its disposal shall be seen as parts of a larger entity, and each component shall be selected so as to be compatible with the others.

The operator shall examine and the regulatory body shall review the different processing options in order to identify the appropriate options and to avoid conflicting requirements that might compromise safety. It is not consistent with an integrated approach to optimize one step in predisposal management of radioactive waste, including decommissioning, in such a way that it imposes significant constraints on following steps or forecloses viable options.

Elements of predisposal management of radioactive waste

Various factors should be balanced when deciding between options in the predisposal management of radioactive waste. These factors include the nature and amount of radioactive waste, occupational and public exposures, environmental effects, human health and safety, and economic considerations.

In predisposal management of radioactive waste, decisions often have to be made at a time when a disposal facility is not available and the waste acceptance requirements for the repository are still unknown. A similar situation would arise if radioactive waste were to be stored for safety reasons or other reasons over extended periods of time. In both cases it should still be considered whether, from the point of view of safety, the radioactive waste should be stored in a raw, treated or conditioned form. In making such decisions, the anticipated needs of any future steps in radioactive waste management, in particular disposal, shall, as far as possible, be considered and applied in processing the waste.

When it is proposed to store radioactive waste or to defer decommissioning for an extended period of time, consideration shall be given to the principle that "radioactive waste shall be managed in such a way that will not impose undue burdens on future generations".

At various stages in the process of predisposal management of radioactive waste, the radioactive waste shall be characterized in terms of its physical, chemical, radiological and biological properties. Such characterization shall serve to provide information relevant to process control and assurance that the waste or waste package will meet the acceptance criteria for storage, transport and disposal. Provisions shall be made for identifying, assessing and dealing with waste or waste packages that do not meet process specifications or disposal criteria. Appropriate collection or segregation may expedite the achievements of such goals.

Waste generation

To keep radioactive waste arising’s to the minimum practicable (Principle, careful planning shall be applied to the design, construction, operation and decommissioning of nuclear facilities.

Measures to control radioactive waste generation, in terms of both volume and activity content, shall be considered throughout the lifetime of a nuclear facility, beginning with the design phase; through the selection of materials for the construction of the facility; by the control of materials and the selection of the processes, equipment and procedures throughout the operation of the facility; and through the incorporation, into the design, of features to facilitate future decommissioning.

Reuse and recycling of materials shall be applied to the extent possible to keep the generation of radioactive waste to the minimum practicable and to contribute to the sustainable use of natural resources.

Authorized discharge, authorized use and clearance of materials from regulatory control, if necessary after an appropriate treatment and/or a sufficiently long storage period, can be effective in reducing the volume and amount of radioactive material that requires further processing. However, it shall be ensured that these management options, if implemented, are in compliance with the conditions and criteria established by the national regulatory body. In the application of such options, the regulatory body shall ensure that due account is given to non-radiological hazards.

Waste processing

Materials with characteristics that make them unsuitable for authorized discharge, authorized use or clearance from regulatory control and for which no further use is foreseen shall be processed as radioactive waste. Processing of waste may yield waste or material that is suitable for authorized discharge, authorized use or clearance from regulatory control.

The main purpose of processing radioactive waste is to produce a waste, packaged or unpackaged, that fulfills the acceptance requirements for disposal. The requirements for handling, transport and storage of waste packages shall also be fulfilled.

Waste shall be processed in such a way that the safety of the operations is appropriately ensured under normal conditions, that measures are taken to prevent the occurrence of incidents or accidents, and that provisions are made to mitigate the consequences should accidents occur. The processing shall be consistent with the type of waste, possible needs for storage, the disposal option, and requirements resulting from safety and environmental impact assessments.

Various methods may be applied for processing the different types of radioactive waste. Consideration shall be given to identifying suitable options and to assessing the appropriateness of their application. It shall be decided within the overall approach to radioactive waste management to what extent waste has to be processed, with account taken of the quantities, activities and physical and/or chemical nature of the radioactive waste to be treated, the technologies available, the storage capacity, and the availability of a disposal facility.

Radioactive waste shall be processed in such a way that the resulting waste, packaged or unpackaged, can be safely stored and retrieved from the storage facility for disposal. Considerations relating to safe storage shall include possible reactions within the waste form and between the waste and the waste container, and the compatibility of the waste package with the storage environment. The radioactive waste shall be processed and the container shall be selected to ensure sufficient stability in all respects. They shall also be compatible with the disposal option.

Preteeatment

Pretreatment may include operations such as waste collection, segregation, chemical adjustment and decontamination. Carrying out such operations requires an appropriate characterization of the waste which serves to enable the appropriate allocation of treatment and conditioning processes. One result of pretreatment of radioactive waste is to reduce the amount of radioactive waste that would be subject to additional processing and disposal. A further result of pretreatment is to adjust the characteristics of the remaining radioactive waste that might require treatment, conditioning and disposal to make it more amenable to additional processing and disposal.

All waste considered radioactive shall be collected. Decisions with respect to additional pretreatment (segregation, decontamination and chemical adjustment) shall be based upon appropriate consideration of the characteristics of the waste and of the requirements imposed by subsequent steps in the national programme of radioactive waste management (treatment, conditioning, transport, storage and disposal).

Treatment

Treatment of radioactive waste includes, when necessary, removal of radionuclides, reduction of volume and change of composition. Important goals of radioactive waste treatment are to enhance safety, in the short term by making immediate improvements in the characteristics of the waste, and in the long term as one of a series of steps contributing to the safe predisposal management of radioactive waste.

In making decisions with respect to the treatment of radioactive waste, account shall be taken of the plan for predisposal waste management and the interdependences between the basic steps in radioactive waste management. Safety shall be the overriding consideration.

Conditioning

Conditioning of radioactive waste includes operations such as immobilization and packaging. The purpose of conditioning is to produce a packaged solid waste form compatible with the selected disposal option and which also meets the requirements for transport and storage.

In selecting the conditioning process, the operator shall consider whether safety would benefit from the use of a matrix material and shall ensure compatibility of the radioactive waste with the selected materials and processes.

Waste packages shall be designed and produced such that radionuclides are confined under both normal conditions and the accident conditions assumed to occur in handling, storage, transport and disposal.

Storage of radioactive waste

Within the context of predisposal management of radioactive waste, storage refers to the placement of radioactive waste in a nuclear facility where appropriate isolation and monitoring are provided. In radioactive waste management, storage may take place between and within the basic radioactive waste management steps. Storage may be used to facilitate the next step in radioactive waste management, to act as a buffer within and between radioactive waste management steps, or in awaiting the decay of radionuclides until authorized discharge, authorized use or clearance can be allowed.

Radioactive waste may be stored in solid, liquid or gaseous form or as raw, pretreated, treated or conditioned waste. The intention of storage is that the waste will be retrieved for authorized discharge, authorized use or clearance or for processing and/or disposal at a later time. The criteria for acceptance of waste packages in a storage facility shall therefore take account of the known or likely requirements for subsequent radioactive waste disposal. Safety requirements for the protection of human health and the environment shall be met by appropriate design, construction, operation and maintenance of the respective facilities, including provision for the eventual retrieval of the waste.

The radioactive waste storage facility shall be designed on the basis of the assumed conditions for its normal operation and assumed incidents or accidents. It shall be designed and constructed for the likely period of storage, preferably with passive safety features, with the potential for degradation taken into account. Provisions shall be made for regular monitoring, inspection and maintenance of the waste and the storage facility to ensure continued integrity. The adequacy of the storage capacity should be periodically reviewed, with account taken of the predicted waste arising and the expected life of the storage facility.

For physically mobile forms of waste, eventual problems with the integrity of the containment can be mitigated if appropriate redundant storage capacity is available.

For liquid waste, agitation, for example, through stirring or pulsing, shall be provided, where necessary, to avoid precipitation of solids dispersed in the liquid.

Gas generation by radiolysis or chemical reaction may be associated with the storage of radioactive waste. The concentration of gases in air shall be kept below hazardous levels to avoid, for example, explosive gas/air mixtures.

The storage facility shall be designed in such a way that the waste can be retrieved whenever required.

If necessitated by the nature of the radioactive waste, dissipation of heat from the waste shall be ensured and criticality shall be prevented.

If radioactive waste containing short lived radionuclides is intended for eventual authorized discharge, authorized use or clearance, it shall be ensured that it is stored for a sufficiently long period of time for the radionuclides to decay below defined activity levels.

If, after storage, the radioactive waste does not meet the acceptance criteria for disposal, the operator shall conduct the necessary waste processing.

Acceptance criteria for radioactive waste disposal

Radioactive waste destined for disposal shall be processed to meet the acceptance criteria for disposal established with the approval of the regulatory body. These criteria define the radiological, mechanical, physical, chemical and biological properties of the waste and of any package.

Packages containing radioactive waste intended for transport shall comply with limits established in the IAEA Transport Regulations, for example, on radionuclide inventories, external dose rates and surface contamination. Criteria to meet handling and emplacement requirements at the disposal facility and to facilitate the identification of waste packages shall also be taken into account.

Decommissioning

Decommissioning plan

Decommissioning of nuclear facilities comprises:

a) preparation and approval of a decommissioning plan;

b) the actual decommissioning operations;

c) the management of waste resulting from the decommissioning activities.

A decommissioning plan shall be developed for each nuclear facility, unless otherwise required by the regulatory body, to show that decommissioning can be accomplished safely. Account shall be taken of the eventual need to decommission a facility at the time it is being planned and constructed. For example, in the selection of construction materials, a number of factors have to be balanced with decommissioning in mind. Properly chosen materials can reduce the formation of activation products during operation and help to minimize the radiation exposures of the workforce engaged in decommissioning.

The decommissioning plan shall be reviewed regularly and shall be updated as required to reflect, in particular, changes in the facility or regulatory requirements, advances in technology and, finally, the needs of the decommissioning operation. If an abnormal event occurs, a new decommissioning plan or modification of the existing decommissioning plan may be necessary.

During the implementation of the decommissioning plan, revisions or amendments may need to be made to the plan in the light of operational experience gained, new or revised safety requirements, or technological developments.

Decommissioning operation

When it has been decided to shut down a nuclear facility, the operator shall submit an application for permission to decommission the facility for approval by the regulatory body, together with the proposed final decommissioning plan. If it is intended to defer decommissioning, it shall be demonstrated in the final decommissioning plan that such an option is safe. Furthermore, a line of reasoning shall be provided to show that no undue burdens are imposed on future generations.

If final shutdown occurs before a decommissioning plan is prepared, decommissioning of the facility shall not be started until a satisfactory decommissioning plan has been approved by the regulatory body, unless otherwise decided by the regulatory body.

If the shutdown of a facility is sudden, as, for example, in the event of a severe accident, the facility shall be brought to a safe state before decommissioning is started in accordance with an approved decommissioning plan.

Decommissioning activities may generate large volumes of waste over short time periods, and the waste may vary greatly in type and activity and may include large objects. The operator shall ensure that appropriate means are available to manage the waste safely.

Dismantling and decontamination techniques shall be chosen which minimize waste arisings and airborne contamination.

Decommissioning activities such as decontamination, cutting and handling of large equipment and the progressive dismantling or removal of some existing safety systems have the potential for creating new hazards. The safety impacts of the decommissioning activities shall be assessed and managed so that these hazards are mitigated.

Completion of decommissioning

Before a site may be released for unrestricted use, a survey shall be performed to demonstrate that the end point conditions, as established by the regulatory body, have been met.

If a site cannot be released for unrestricted use, appropriate control shall be maintained to ensure protection of human health and the environment.

A final decommissioning report, including any necessary final confirmation survey, shall be prepared and retained with other records, as appropriate.

Safety of facilities

In compliance with Principle 9 on the safety of facilities, the safety of operations involving radioactive waste and the decommissioning of nuclear facilities shall be ensured by means of safety assessment and quality assurance. Safety and environmental impact assessments before commissioning shall be performed to demonstrate that the facilities and operation will be adequately safe. A quality assurance programme shall be conducted to provide the necessary confidence throughout all stages of design, construction and operation that all relevant requirements and criteria are met.

Safety and environmental impact assessments

Facilities and activities for predisposal management of radioactive waste, including decommissioning activities, shall be subject to safety and environmental impact assessments in order to demonstrate that they are adequately safe and, more specifically, that they will be in compliance with safety requirements established by the regulatory body.

These safety and environmental impact assessments shall address the facility’s structures, systems and components, the waste to be processed and all associated operational work activities, and shall encompass both normal operation and anticipated incidents and accidents. In the latter case, the safety and environmental impact assessments shall demonstrate that appropriate measures have been taken to prevent incidents or accidents and that consequences would be mitigated should an incident or accident occur.

The extent and detail of the safety and environmental impact assessments shall be commensurate with the complexity and the hazard associated with the facility or operation.

The results of the safety and environmental impact assessments shall be used to bring appropriate safety related improvements to predisposal waste management activities and decommissioning activities in order to reduce the likelihood of incidents or accidents and to mitigate their consequences should they occur.

Quality assurance

A comprehensive quality assurance programme shall be applied to all stages and elements of predisposal radioactive waste management having a bearing on safety. It may include the siting, design, construction, operation and maintenance of radioactive waste management facilities. It also applies to the decommissioning of nuclear facilities and includes the maintenance and archiving of related documents and records, and all associated work activities and operations. Features important to safe operation, and therefore requiring consideration in the quality assurance programme, shall be identified on the basis of the results of the safety and environmental impact assessments.

The predisposal quality assurance programme shall be applied to the processing of the waste to ensure that all waste acceptance requirements are fulfilled. This will provide an assurance of adequate quality and will ensure compliance with the relevant standards and criteria.

MITIGATING NON-RADIOLOGICAL CONSEQUENCES

Psychological consequences of nuclear or radiological emergency

Functional requirement 16 of GSR Part 7 states:

"The government shall ensure that arrangements are in place for mitigation of non-radiological consequences of a nuclear or radiological emergency and of an emergency response.

Non-radiological consequences of a nuclear or radiological emergency and of an emergency response shall be taken into consideration in deciding on the protective actions and other response actions to be taken in the context of the protection strategy (see Requirement 5).

Arrangements shall be made for mitigating the non-radiological consequences of an emergency and those of an emergency response and for responding to public concern in a nuclear or radiological emergency. These arrangements shall include arrangements for providing the people affected with:

a) Information on any associated health hazards and clear instructions on any actions to be taken (see Requirement 10 and Requirement 13);
b) Medical and psychological counselling, as appropriate;
c) Adequate social support, as appropriate.

Arrangements shall be made to mitigate the impacts on international trade of a nuclear or radiological emergency and associated protective actions and other response actions, with account taken of the generic criteria in Appendix II. These arrangements shall provide for issuing information to the public and interested parties (such as importing States) on controls put in place in relation to traded commodities, including food, and on vehicles and cargoes being shipped, and on any revisions of the relevant national criteria.

Arrangements shall be put in place for any actions taken, beyond those emergency response actions that are warranted, by members of the public and by commercial, industrial, infrastructural or other governmental or non-governmental bodies to be, to the extent practicable, promptly identified and appropriately addressed. This shall include the designation of organization(s) with the responsibility for monitoring for, identifying and addressing such actions."

Material based on

Mental Health and Social Issues Following a Nuclear Accident. The case of Fukushima. Jun Shigemura & Rethy Kieth Chhem. Springer Japan 2016. 146 p. DOI 10.1007/978-4-431-55699-2

Joshua C. Morganstein, James C. West, Lester A. Huff, Brian W. Flynn, Carol S. Fullerton, David M. Benedek, and Robert J. Ursano. Psychosocial Responses to Disaster and Exposures: Distress Reactions, Health Risk Behavior, and Mental Disorders

Mental health is an essential aspect of healthcare, including disaster response, and a substantial part of the global challenge of healthcare. Although most people will show resilience in the face of disasters, these and other types of extreme events also result in distress reactions, health risk behaviors, and mental disorders (see Fig. 25), collectively termed "psychosocial" responses for the purposes of this chapter. These events affect a wide range of individuals, including direct victims and their families, surrounding community members, and first responders. Disasters that result from intentional acts or technological failures ("human-made disasters"), such as a nuclear exposure, often produce the most severe psychological symptoms. Community planning, training and education for responders, and credible and timely communication from leaders and trusted authorities are important aspects of managing psychosocial response to nuclear exposures.

Fig. 25. Mental health responses to disasters and emergencies

Knowledge of psychosocial responses to disaster comes from extensive observation of community behaviors following natural and man-made disasters. In addition, there is evidence from recent and historical nuclear accidents and the field of bioterrorism that enhance our understanding of how individuals and communities specifically respond to fears of exposure to chemical, biological, radiological, and nuclear material. Patterns of psychosocial response are influenced by community and cultural characteristics. The response of community leaders and technical experts to a disaster can influence the distress and behaviors of disaster communities, both positively and negatively.

Nuclear accidents have two characteristics that are of importance to understanding their unique psychosocial response. First, these incidents are heavily influenced by human factors. Second, nuclear accidents involve uncertain exposure to hazards not well understood by the general population. Very few people understand the risks posed by nuclear material and contamination. Usually anything nuclear or associated with radiation is seen as an ominous threat that generates responses out of proportion to actual danger. Credible and accurate risk communication is essential to disaster recovery. Community responses to past nuclear exposures, including World War II, Three Mile Island, Chernobyl, and Fukushima, demonstrate that psychosocial consequences were greater than the actual illnesses and injuries directly attributed to radiation or contamination. Understanding community response to nuclear accidents offers valuable information to assist governments, community leaders, and healthcare personnel.

Psychosocial Responses to Disasters

Distress Reactions, Health Risk Behaviors, and Mental Disorders

In the immediate aftermath of a disaster, distress reactions predominate. Individuals feel a sense of vulnerability and often engage in blaming, scapegoating, and expressions of anger at government and other leaders perceived as responsible.

Demoralization and a loss of faith may also occur. Many individuals experience insomnia, irritability, and feelings of distractibility. Some individuals present to healthcare settings with physical symptoms as a manifestation of psychological distress. Symptoms such as headache, dizziness, nausea, fatigue, and weakness are common in the wake of a disaster even when an identifiable physical disorder cannot be found. These are normal reactions to an extraordinary event. Planning for these distress reactions requires ensuring adequate resources to respond to individuals with distress symptoms in a timely and supportive manner and triage at emergency care settings to enable management of other physical and mental disorders.

In addition to distress responses, several health risk behaviors are known to increase following disasters. Increased use of alcohol, caffeine, and tobacco are common coping mechanisms and often represent self-medicating of distress symptoms. Reduced use of social activities and self-imposed travel restrictions occur as well and may result in decreased access to social support networks and adverse economic impacts on the larger community. Following disasters, intimate partner violence and overall levels of violence may increase as family distress and community concern about resources are increased.

Some individuals develop mental disorders following a disaster. The most widely studied of these disorders (but not the only one) is posttraumatic stress disorder (PTSD). Many studies suggest that approximately 10–20 % of those exposed to a traumatic event will develop PTSD, though many more individuals will experience milder symptoms, which can persist and become problematic over time. The course of PTSD varies with some individuals recovering and some showing symptoms long after the initial incident (See Fig. 26).

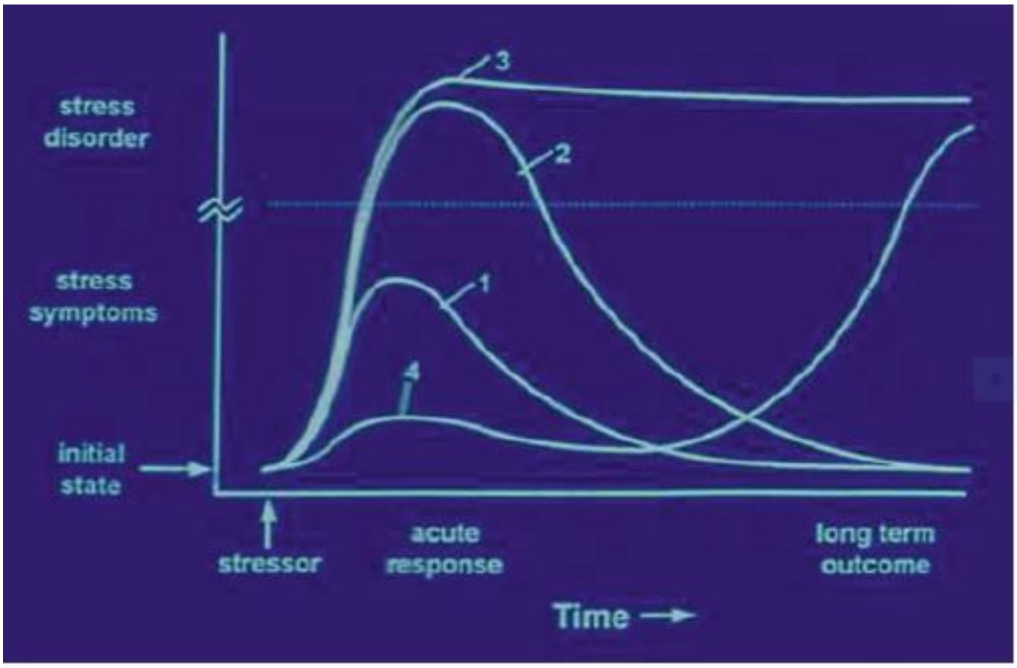


Fig. 26. Posttraumatic stress disorder is not the only trauma related disorder nor perhaps the most common

People exposed to disaster are at increased risk for depression, generalized anxiety disorder, panic disorder, and increased substance use. In some studies, suicide rates have also been shown to increase although this is not universal.

Unique Aspects of Nuclear Exposures

Nuclear incidents can affect very large numbers of individuals and involve technological failures or be the result of man-made errors leading to exposures. They result in unique psychosocial responses related to the uncertainty of an invisible and mysterious chemical agent along with fears of permanent contamination such as:

- Contamination fears
- Chronic focus on bodily symptoms

- Poor perception of self-health
- Long-term distress and worry
- Mistrust in authorities

The inability to see and touch radiation and its depiction in books, movies, and other popular media as a frightening and inescapable force cause nuclear spills to produce adverse psychosocial responses that significantly exceed the actual health risks. While many people have preconceptions about the impact of nuclear material, information and education are important aspects of population health management. In the aftermath of nuclear exposure, open and honest communication from government officials and leaders involved in managing the incident is critical in building trust and alleviating psychological distress.

World War II introduced the world to the extraordinary psychosocial effects of large-scale nuclear exposure that resulted from the use of atom bombs during war. Atomic bomb survivors in Japan experienced a chronic fear of long-term contamination, increased worry about their physical well-being, and an ongoing sense of harm and bodily deterioration despite extensive education about the science and medical impact of nuclear exposure. Many years after the incident, these individuals continue to attribute new physical symptoms to nuclear exposure despite medical reassurance these symptoms were unrelated.

In more recent history, accidents at Three Mile Island, Chernobyl, and Fukushima have further demonstrated the widespread and long-lasting psychosocial effects that occur in the aftermath of a nuclear exposure. The accident at Three Mile Island was a partial nuclear meltdown that occurred in 1979 in one of the two Three Mile Island nuclear reactors in the United States. It was the worst accident in US commercial nuclear power plant history. Nearly 1 year later, incident responders had elevated levels of distress. Following the restart of the reactor 6 years after the incident, local residents reported increased anxiety and worry, specifically due to fear of cancer and loss of trust in the authorities. For nearly 10 years post-incident, Three Mile Island residents were found to have increased levels of distress and persistent elevation in blood pressure when compared to similar people who were living at greater distance from the incident.

Chernobyl, the site of a nuclear power plant explosion in 1986, was the most disastrous nuclear accident until the incident at Fukushima in 2011. The Chernobyl incident resulted in feelings of helplessness regarding long-term health as well as decreased fertility rates, the latter suggesting a more negative future outlook on life. Research also revealed high levels of general psychological distress and persistent focus on physical symptoms, not unlike the experience of World War II survivors. Nearly a quarter century after the events at Chernobyl, those who served as first responders, cleanup workers, and mothers who had small children at the time of the incident continue to experience elevated levels of depression, anxiety, and posttraumatic stress and report themselves as having poor health. The lack of trust held by citizens in government and authorities appears to have played a major role in the development of long-term health effects following Chernobyl, demonstrating the importance of the relationships between government and citizens in affecting population health.

The disaster at Fukushima in 2011 was a unique hybrid event that included a tsunami, earthquake, and subsequent nuclear exposure. In addition to an increase in depression, anxiety, and PTSD, increased rates of delirium and psychosis were reported in the early aftermath of the disaster, most notably in those who were displaced from their home. In the 7 months following the event, suicide rates were reported as increased among females in disaster-stricken areas. Similar to other historical nuclear disasters, increased anxiety and distress were associated with fears of exposure and contamination, suggesting the need for education of both citizens, and relief workers remain as critical aspects of managing a nuclear exposure.

Because of the unique psychological and medical challenges that result from a nuclear exposure, advance planning for these types of catastrophic events is important to aid governments, responders, and victims. Effective planning and preparedness may represent our best hope for reducing adverse psychosocial consequences.

Psychosocial Stages of Disaster Response

Governments and organizations that plan for and respond to disaster events need an understanding of the emotional and behavioral responses to disaster events. Often, there are phases to this response (See Fig. 27).

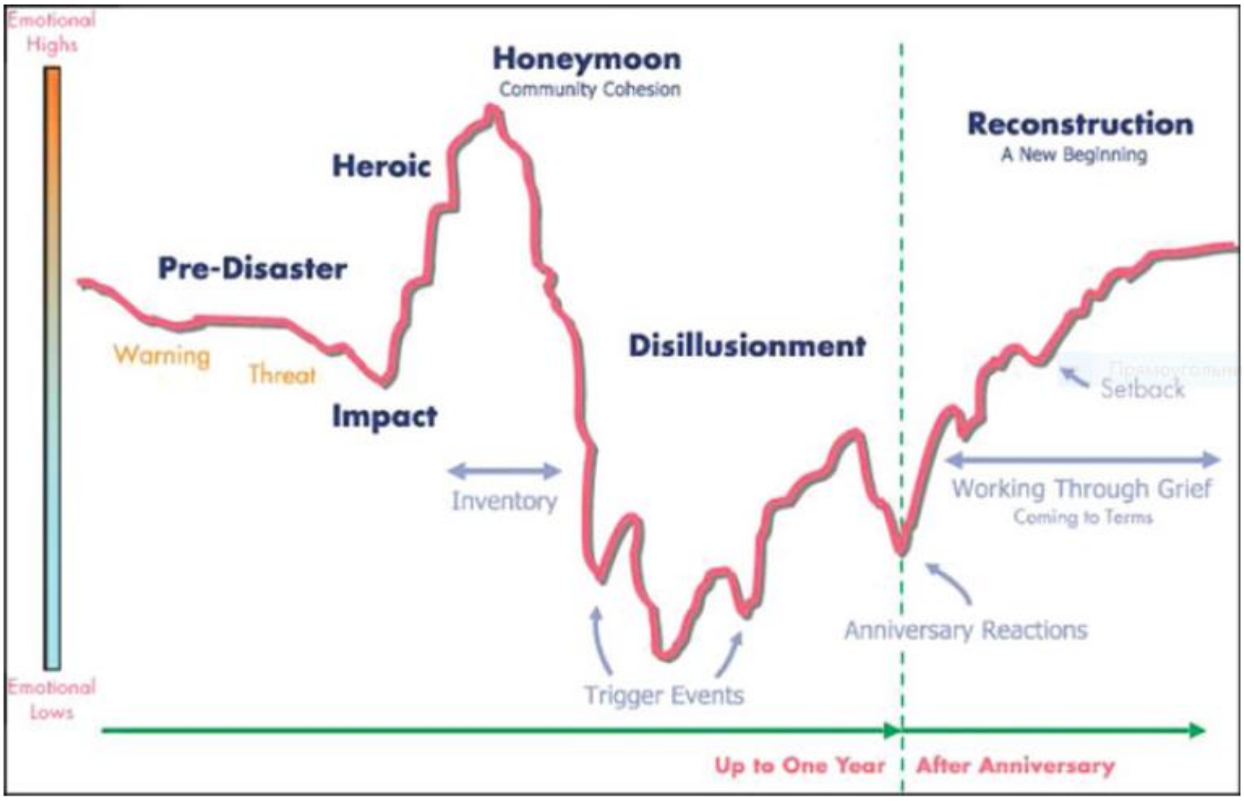


Fig. 27. Phases of a disaster

Individuals or communities do not progress through these phases at exactly the same time or the same order. However, an understanding of the psychosocial factors that predominate in each phase (See Table below) is helpful for policy development, response planning, and the training and education of personnel that deliver services to disaster victims.

Psychological and behavioral symptoms during disaster phases

Pre-disaster;	Vulnerability, worry, remorse;
Impact;	Fear, confusion, numbness, disbelief;
Heroic;	Flashbacks, hyperarousal, anger, irritability, physical symptoms;
Honeymoon;	Collaboration, hope, optimism, openness to mental healthcare;
Disillusionment;	Disappointment, resentment, fatigue;
Reconstruction;	Acceptance, finding meaning, posttraumatic growth;

Phases of a Disaster

A ***pre-disaster phase*** begins when an event is anticipated or advanced warning is given. This phase is highlighted by feelings of vulnerability and worry about safety. Individuals who do not heed advanced warnings to take recommended actions, such as sheltering in place or evacuation, may also experience significant remorse and feelings of responsibility for subsequent injury to loved ones or damage to property.

The ***impact phase*** occurs immediately after an acute event and consists of strong emotions, including feelings of disbelief, numbness, fear, and confusion. During this time, if the scope of a disaster broadens, the psychological effects typically increase. The impact phase may be brief, such as an earthquake. It can also be very long as in a slow-rising flood or an undetected radiological leak. Duration will affect both the response and the impact. In addition, the response of a population is affected by the culture and history of communities. Incorporating cultural understanding of communities and their values, leadership, and support systems is an important element of effective planning and response efforts.

Next is the ***heroic phase***. This phase often lasts days to weeks in situations involving a short event period, but may be extended in disasters that occur over a longer period of time. Injury of loved ones or separation of family members can increase anxiety and worry and decrease the energy available for immediate problem solving. This phase is frequently accompanied by the initial appearance of assistance from outside communities, government agencies, or other countries.

Disaster victims begin to adapt to the new environment and outsiders appear in the disaster community. Convergence begins during this phase, as people come into the disaster zone looking for family, friends, and even pets from which they have been separated. There is also a gathering of displaced individuals who have fled their homes. Intrusive symptoms (distressing recollections of explosions, fire, building collapse, and others, in the form of flashbacks or nightmares) emerge during this phase. Hyperarousal is also common, where individuals constantly feel tense and irritable. Physical symptoms, such as fatigue, dizziness, headaches, and nausea, along with anger, irritability, and social withdrawal, may also emerge. During this phase, personnel providing mental health interventions recognize the normal range of emotions and behaviors and respond to disaster victims with empathy, caring, and support for basic elements of living.

The ***honeymoon phase*** often follows. This coincides with more extensive availability of government and volunteer assistance and community bonding as a result of sharing the catastrophic experience as well as the giving and receiving of assistance. Survivors are often more hopeful during this phase and experience an optimism that the help they will receive will make them whole again and restore their lives to “normal.” Governments can use this time to build positive relationships with affected communities by ensuring basic needs are met for food, water, and shelter and that resources are distributed equitably. In addition, clear and effective communication about what type of aid will be provided assists with setting expectations and helping reduce uncertainty. Providing disaster response workers with items necessary to live and work safely and effectively can reduce the diversion of resources intended for victims. Disaster workers who are specifically aiding with psychosocial issues are most likely to be perceived as helpful during this phase, be readily accepted by community members, and develop a foundation from which to provide assistance in the difficult phases ahead.

Commonly, a ***disillusionment phase*** follows this honeymoon. Disillusionment is marked by feelings of disappointment and resentment, as disaster assistance agencies and volunteer groups begin to withdraw from the community. The magnitude of individual and collective loss may be realized. Hopes for aid and restoration of the pre-disaster emotional and physical environment may not be fully met. Individual and community economic losses may add to an already stressed population. The sense of community is weakened as individuals focus on their personal needs or the extent to which these needs are still unmet. Resentment may surface as survivors receive unequal compensation for what they perceive to be equal or similar damage and issues of social justice emerge. In addition, neighboring communities less impacted by the disaster often return to life as usual, which can discourage and alienate those who were more severely impacted. During this phase, survivors may become physically exhausted due to the enormity of multiple demands, including financial pressures, family discord, bureaucratic hassles, and a lack of free time for recreation or self-care. Long-term displacement and loss of familiar home and surroundings can be a particularly challenging stressor. Health problems and exacerbation of preexisting conditions emerge due to ongoing stress and fatigue. Governments can anticipate difficulties as disaster assistance begins to diminish and provide survivors with anticipatory guidance in advance. Unity among formal and informal community leaders in anticipating and communicating upcoming changes or transitions is helpful. The disaster "anniversary" experience may occur during this phase and can be a critical opportunity for leaders to support disaster victims. This can be done through memorializing and creating meaning from the devastating events that have occurred. Failure to effectively address a disaster anniversary experience can further demoralize survivors, enhance feelings of frustration, and exacerbate underlying psychosocial distress.

The ***final phase*** often seen is that of ***reconstruction*** which may last for years. Survivors attempt to rebuild their lives and social and occupational identities by returning to old jobs or finding new work. They will also rebuild homes and resume or establish new social ties and emotional support systems. For some survivors, this phase is marked by an acceptance of new circumstances, including the changes and losses that have occurred. Individuals who are able to find meaning may experience posttraumatic growth, ultimately emerging from the disaster event with an increased sense of personal strength.

Individuals may progress through these phases at variable rates. Persons involved in planning and delivering care to victims of disasters may observe that individuals show emotional symptoms over different timelines in response to the same event. Moreover, depending on the severity of the trauma, available resources, coping skills, as well as subsequent disasters or other types of setbacks, individuals may develop persistent symptoms requiring prolonged treatment. Anger may be directed at caregivers and community leaders if these important factors are not sufficiently accounted for in medical and psychosocial response plans.

Common Psychosocial Responses Following Exposure

Large-scale nuclear exposure events result in a range of psychosocial responses that are similar to other disasters including somatic concerns and belief that they are contaminated or exposed even when little data may support the concern. Although many people will be resilient, some will experience a range of transient and mild stress reactions. Some victims of nuclear exposure will experience more long-term and disabling psychological symptoms. The reestablishment of societal order and organization with the passage of time may help; and early focus on normal and adaptive functioning may speed recovery.

Emotional symptoms may include shock, anger, despair, emotional numbing, terror, guilt, grief or sadness, irritability, helplessness, loss of interest in activities, and dissociation. Cognitive effects may include impaired concentration and decision-making, memory problems, disbelief, confusion, distorted thinking, decreased self-esteem and motivation, self-blame, intrusive thoughts and memories, and worry. Social and interpersonal impairment, alienation, withdrawal, conflict, work problems, and educational impairment may result. Somatic complaints may include fatigue, disturbed sleep, headaches and other pain symptoms, and gastrointestinal problems. When these symptoms have no detectable medical cause, they are often referred to as medically unexplained physical symptoms (MUPS). These can be very resistant to intervention.

Community Impact and Responses

Much of our knowledge about community responses comes from populations exposed to natural disasters. As described earlier, response to a natural disaster often follows a pattern of initial social support mobilization followed by deterioration in social support. However, in nuclear events, patterns change. The honeymoon phase can be diminished or absent as outside groups may be reluctant to respond to affected areas out of fear of exposure or contamination. In contrast to a natural disaster, the expectation of accountability or blaming will be stronger following nuclear accidents given the inherent human factors involved in causing the event.

Evacuations and Community Disruption

Following a large nuclear incident, entire communities are often evacuated. The Chernobyl accident resulted in more than 200,000 people permanently relocated. In Fukushima, approximately 380,000 individuals were relocated following the nuclear disaster. Individuals who are immediately displaced may not achieve permanent housing for several years, and families and communities will live with uncertainty for a long time. Following nuclear disasters, entire communities may cease to exist, and their members are scattered among evacuation centers with similarly displaced and highly stressed groups of evacuees. This decreases the ability of victims to reduce stress by seeking connections with community members. Groups forced to cohabitate in relocation centers may have preexisting social or cultural conflicts, and new communities who do not know each other often have fears of safety. Ten years after Chernobyl, there was a prolonged tendency toward uncertainty and mistrust of government, even in communities not heavily contaminated, and tendencies to attribute symptoms and illness to radiation exposure or contamination.

Stigma Surrounding Individuals with Nuclear Exposure

Unlike natural disasters, victims of nuclear events are often stigmatized in many ways. The most common reason victims face stigma is the fear that they bring nuclear contamination with them out of the evacuation zone. This occurred to evacuees following both the Chernobyl and Fukushima nuclear disasters. In an attempt to reduce stigma following the Goiania disaster, more than 8000 people applied for certification from the Brazilian government asserting that they were free of contamination. They did so in order to overcome discrimination in boarding commercial flights and securing hotel reservations. Similar to past disease epidemics, families of victims of nuclear events find it difficult to bury their dead following the event due to fear of radiation from the body or contamination of soil and groundwater. Following Goiania, protesters blocked the burial of victims in the local cemetery. Those displaced from their homes and neighborhoods also find themselves competing for existing resources, community services, and employment.

While struggling with the loss of their homes and communities, displaced persons have been housed in temporary structures or must compete for available permanent housing. All familiar community services previously available are no longer accessible, and those displaced must either attempt to establish new services or compete for existing services in their new communities.

It is clear that anxiety concerning radiation exposure and its consequences can have a significant and lasting effect on communities and may persist for years, often generations beyond the event. Adults born 25 years after the Chernobyl incident still showed significant anxiety over effects of radiation exposure. Research on communities affected by contamination disasters indicates that families have difficulty perceiving homes and communities as safe or desirable, leaving them disconnected from familiar surroundings and resources. The anxiety for victims of nuclear disasters is often compounded by distrust of and hostility toward government and scientific experts. In technological disasters, the distress over loss is increased by the knowledge that the cause is man-made. In the case of Three Mile Island, distrust of authorities was very high after the accident and remained high even after other measures of distress had normalized.

Nuclear events impact individual physical and mental health, family and community cohesion, and even the culture of a nation. These impacts may last beyond individual lifetimes.

Leadership Communication about Disaster Exposure and the Impact on Psychological Health of a Population

Effective leadership is critical to all disaster preparedness, response, and recovery. The positive impact of successful leadership and the negative effects of inadequate and failed leadership are well documented. It is also a consistent theme noted in popular nonfiction literature concerning extraordinary events.

Effective leadership in disasters is a complex task. It requires an array of skills demanded by few other roles. An effective leader in this context needs to integrate and balance the science of the disaster event, complex and changing real-world response, political realities, and compassion. Leaders must be able to communicate effectively within their own organizations, across organizational boundaries, and with a wide variety of diverse elements of the population. The ability to communicative effectively in disaster situations of all types is a key characteristic of successful leaders.

Misunderstanding of Panic and Impact on Leadership Decision-Making

The term panic is widely used in common speech and in the media. It is used to cover a broad, yet poorly specified range of both emotion and behavior. The wide and unscientific use of the term has led to a number of false and, ultimately, dangerous assumptions. Panic – meaning disorganized behavior – is not common in disasters. Common misperceptions have resulted in disaster and emergency preparedness and response based on misunderstanding rather than real experience and evidence. There is a common misconception that panic is widespread and easily triggered. An assumption that panic will often and easily occur can lead to poor preparedness and response planning and execution. Leaders should know about the nature and dynamics of community fear, concern, and distress (and other far more common anxiety-related consequences) and prepare and respond accordingly. Effective leaders communicate accurate information effectively. When this occurs, all benefit. Providing accurate information and assurances consistent with the principles of evidence-based risk and crisis communication enhances the perception of leaders by the public. It also promotes appropriate pro-social behaviors in the impacted population.

Disasters produce a range of psychosocial responses including distress reactions, health risk behaviors, and mental disorders. In many cases, fear of nuclear exposure causes a range of psychological and physical symptoms that exceed actual health risk. Community responsiveness, cohesion, communication, and leadership all play an important role in enhancing adaptive behaviors and emotional recovery after a nuclear event. Governments and community leaders that understand the psychosocial nature of disaster phases can anticipate needs and plan accordingly. Training and education for all personnel who write policy, plan and coordinate activities, or directly respond to disasters, allow for a better understanding of unique and diverse disaster-specific, psychosocial issues.

There is growing worldwide recognition that psychosocial issues are an integral part of health, specifically disaster preparedness and response. Recommendations made to the United Nations in support of the Hyogo Framework for Action 2, which provides guidance to the international community on disaster risk management, observed that a fundamental aspect of managing the well-being of a population following a disaster is to ensure that psychosocial issues are treated as an integral part of healthcare.

The visible nature of physical injuries often leads those managing a disaster to prioritize these and can result in delayed care or a failure to identify the significant psychosocial effects of the event that invariably occur. Historical experience of nuclear exposures demonstrate that psychosocial effects are generally far more common and experienced over a much longer period of time than observable physical injuries or associated medical conditions. Ensuring that psychosocial concerns are anticipated in response to a nuclear disaster allows governments, community leaders, and healthcare personnel to more effectively prepare for and respond to the event, which decreases the negative impact on an affected population.

Timely and accurate ongoing communication from credible, trusted sources is an essential aspect of managing disasters and particularly important in response to nuclear accidents. An appreciation of the unique cultural aspects and variations in communication style will enhance the ability of leaders to effectively inform and partner with all those affected by a nuclear event.

Socio-Economic consequences of nuclear or radiological emergency

Material based on

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The Socio-Economic Impact of the Chernobyl Nuclear Accident

The Chernobyl nuclear accident, and government policies adopted to cope with its consequences, imposed huge costs on the Soviet Union and three successor countries, Belarus, the Russian Federation and Ukraine. Although these three countries bore the brunt of the impact, given the spread of radiation outside the borders of the Soviet Union, other countries (in Scandinavia, for instance) sustained economic losses as well.

The costs of the Chernobyl nuclear accident can only be calculated with a high degree of estimation, given the non-market conditions prevailing and volatile exchange rates of the transition period that followed the break-up of the Soviet Union in 1991. However, the magnitude of the impact is clear from a variety of government estimates from the 1990s, which put the cost of the accident, over two decades, at hundreds of billions of dollars (Belarus, for instance, has estimated the losses over 30 years at US $235 billion).

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

— Direct damage caused by the accident;

— Expenditures related to:

• Actions to seal off the reactor and mitigate the consequences in the exclusion zone;

• Resettlement of people and construction of new housing and infrastructure to accommodate them;

• Social protection and health care provided to the affected population;

• Research on environment, health and production of clean food;

• Radiation monitoring of the environment;

• Radioecological improvement of settlements and disposal of radioactive waste.

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

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

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

This massive expenditure has created an unsustainable fiscal burden, particularly for Belarus and Ukraine. Although capital-intensive spending on resettlement programmes has been curtailed or concluded, large sums continue to be paid out in the form of social benefits for as many as7 million recipients in three countries. With limited resources, governments thus face the task of streamlining Chernobyl programmes to provide more focused and targeted assistance, with an eye to helping those groups that are most at risk from health hazards or socio-economic deprivation.

The main consequences of Chernobyl for the local economy

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

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

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

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

Wages tend to be lower and unemployment higher in the affected areas than they are elsewhere. This is in part the result of the accident and its aftermath, which forced the closure of many businesses, imposed limitations on agricultural production, added costs to product manufacture (particularly the need for constant dosimetric monitoring), and hurt marketing efforts. But equally important is the fact that farm workers in all three countries are among the lowest-paid categories of employees. Employment options outside of agriculture are also limited in Chernobyl-affected regions, but, again, the causes are as much a consequences of generic factors as of Chernobyl specifics. The proportion of small and medium-sized enterprises (SMEs) is far lower in the affected regions than elsewhere. This is partly because many skilled and educated workers, especially the younger ones, have left the region, and partly because — in all three countries — the general business environment discourages entrepreneurship. Private investment is also low, in part owing to image problems, in part to unfavorable conditions for business nationwide.

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

Chernobyl impact and its aftermath on local communities

Since the Chernobyl accident, more than 330 000 people have been relocated away from the more affected areas. 116 000 of them were evacuated immediately after the accident, whereas a larger number were resettled several years later, when the benefits of relocation were less evident.

Although resettlement reduced the population's radiation doses, it was for many a deeply traumatic experience. Even when resettlers were compensated for their losses, offered free houses and given a choice of resettlement location, many retained a deep sense of injustice about the process. Many are unemployed and believe they are without a place in society and have little control over their own lives. Some older resettlers may never adjust.

Opinion polls suggest that many resettlers wished to return to their native villages. Paradoxically, people who remained in their villages (and even more so the "self-settlers," those who were evacuated and then returned to their homes despite restrictions) have coped better psychologically with the accident's aftermath than have those who were resettled to less affected areas.

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

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

The main impact on individuals

As noted in the Chernobyl Forum report on Health, "the mental health impact of Chernobyl is the largest public health problem unleashed by the accident to date." Psychological distress arising from the accident and its aftermath has had a profound impact on individual and community behavior. Populations in the affected areas exhibit strongly negative attitudes in self-assessments of health and wellbeing and a strong sense of lack of control over their own lives. Associated with these perceptions is an exaggerated sense of the dangers to health of exposure to radiation.

The affected populations exhibit a widespread belief that exposed people are in some way condemned to a shorter life expectancy. Such fatalism is also linked to a loss of initiative to solve the problems of sustaining an income and to dependency on assistance from the state.

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

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

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

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

Recommendations for Economic and Social Policy

What is to be done?

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

- Chernobyl-related needs should be addressed in the framework of a holistic view of the needs of the individuals and communities concerned and, increasingly, of the needs of society as a whole;
- Moving away from a dependency culture in the affected areas, the aim must be to help individuals to take control of their own lives and communities to take control of their own futures;
- Efficient use of resources means focusing on the most affected people and communities. The response must take into account the limited budgetary resources at government disposal;
- The new approach should seek changes that are sustainable and long term, and based on a developmental approach;
- The international effort can only be effective if it supports, amplifies and acts as a lever for change in the far larger efforts made by local and national government agencies and the voluntary sector in the three countries.

INTERNATIONAL ASSISTANCE

Providing international assistance

Requirement 3 GSR-7 «Responsibilities of international organizations in emergency preparedness and response», states: «Relevant international organizations shall coordinate their arrangements in preparedness for a nuclear or radiological emergency and their emergency response actions.»

The Inter-Agency Committee on Radiological and Nuclear Emergencies and its Joint Radiation Emergency Management Plan of the International Organizations are examples of such coordination.

Requirement 17 GSR-7 «Requesting, providing and receiving international assistance for emergency preparedness and response», states:

«The government shall ensure that adequate arrangements are in place to benefit from, and to contribute to the provision of, international assistance for preparedness and response for a nuclear or radiological emergency.

Governments and international organizations shall put in place and shall maintain arrangements to respond in a timely manner to a request made by a State, in accordance with established mechanisms and respective mandates, for assistance in preparedness and response for a nuclear or radiological emergency.

Arrangements shall be put in place and maintained for requesting and obtaining international assistance from States or international organizations and for providing assistance to States (either directly or through the IAEA) in preparedness and response for a nuclear or radiological emergency, on the basis of international instruments (e.g. the Assistance Convention), bilateral agreements or other mechanisms. These arrangements shall take due account of compatibility requirements for the capabilities to be obtained from and to be rendered to different States so as to ensure the usefulness of these capabilities».

The **Assistance Convention** states that, *«If a State Party needs assistance in the event of a nuclear accident or radiological emergency, whether or not such accident or emergency originates within its territory, jurisdiction or control, it may call for such assistance from any other State Party, directly or through the Agency, and from the Agency …»*;

and

“*Each State Party shall make known to the Agency and to other States Parties, directly or through the Agency, its Competent Authorities and point of contact authorized to make and receive requests for and to accept offers of assistance”*

The international emergency preparedness and response system is based on:

- The legal framework provided by the Early Notification and Assistance Conventions;
- The Statute of the IAEA;
- IAEA Safety Standards Series No. SF-1, Fundamental Safety Principles, No. SF-1, Principle;
- IAEA Safety Standards Series No. GSR Part 7, Preparedness and Response for a Nuclear or Radiological Emergency, Requirement 17;
- IAEA Nuclear Security Series No. 20, Objective and Essential Elements of a State’s Nuclear Security Regime, Essential Elements 6 and 11;
- Arrangements and agreements made by and between Member States and the Secretariat, and by and between relevant international organizations to improve the system;

- Preparedness arrangements to maintain the capability to respond to nuclear or radiological emergencies, regardless of their origin;
- Arrangements for the exchange of official information for notifying, identifying, assessing, and responding to a nuclear or radiological emergency among States, relevant international organizations and the Secretariat.

Response assistance Network (RANET)

In order to meet States Parties' obligations under the Assistance Convention and the IAEA functions in relation to the Assistance Convention and its Statute, it has been recognized that appropriate mechanisms need to be organized. IAEA Response and Assistance Network (RANET) is intended, inter alia, to strengthen the worldwide capability to provide assistance and advice and/or to coordinate the provision of assistance as specified within the framework of the Assistance Convention for nuclear or radiological emergencies, regardless of their origin, as well as for other nuclear or radiological emergencies.

The aim of RANET is to facilitate:

- The provision of requested international assistance;
- The harmonization of emergency assistance capabilities;
- The exchange of relevant information and feedback of experience related to the provision of international assistance.

In addition, RANET complements other IAEA initiatives to promote emergency preparedness and response among its Member States.

Concept of RANET

RANET provides a compatible and integrated network for the provision of international assistance to minimize the actual or potential radiological consequences of a nuclear or radiological emergency to protect human life, health, property and the environment. It also facilitates the provision of advice and assistance to the requesting State regarding on-scene response activities to regain control of the situation and mitigate the consequences.

RANET facilitates response to specific requests for assistance in accordance with the Assistance Convention and also applies to other nuclear or radiological emergencies.

RANET does not affect the cooperation defined in any bilateral and/or multilateral agreements between States.

Scope of RANET

RANET is a network for providing international assistance, upon request from a State, following a nuclear or radiological emergency, regardless of its origin. RANET is applicable for:

- Nuclear accidents or radiological emergencies in the context of the Early Notification Convention and the Assistance Convention;
- Other nuclear or radiological emergencies;
- Radiological consequences that exceed a State's response capabilities.

RANET does not and will not at any time replace national/State responsibility in emergency preparedness and response.

Responsibilities

States

It is important that States develop and maintain national response capabilities and arrangements, commensurate with identified hazards and threats.

States should make known to the IAEA and to other States, directly or through the IAEA, their Competent Authorities authorized to make requests for, and accept offers of, assistance and their 24-hour point of contact (i.e. National Warning Point).

Identified Competent Authorities should be authorized to make and receive requests for, and to accept offers of, assistance. The relevant permanent mission to the IAEA may also make requests for assistance and receive offers of assistance.

Assistance during a nuclear or radiological emergency could be offered and provided not only through RANET but also via other existing international or bilateral mechanisms. Therefore, the Competent Authorities or the State's permanent mission should coordinate at the national level the process of requesting/ offering assistance.

If a State needs assistance in the event of a nuclear or radiological emergency, whether or not such an event originates on its territory or is under its jurisdiction or control, it may request assistance from or through the IAEA. If the response to an emergency exceeds the State's capabilities, it may submit a request for assistance.

States participating in RANET are responsible for identifying expertise, equipment and materials that could be made available to assist another State in a nuclear or radiological emergency. The expertise, equipment and materials comprise the State's National Assistance Capabilities (NACs) that can be activated to provide assistance either by deployment to the scene or from an external base.

States which have registered the capabilities and resources of private entities in RANET need to ensure that certifications of the registered capabilities and resources are current and authorized for their intended use (see Section 4.5 'Registration of Private Entity Resources').

Requesting and receiving international assistance

Requesting State

A State requesting assistance is responsible for specifying the scope and type of assistance required and, where practicable, providing the IAEA with such information as may be necessary for the assisting party/parties3 to determine the extent to which the request can be met. In the event that it is not practicable for the requesting State to specify the scope and type of the assistance required, the requesting State, as appropriate, consults with the assisting party/parties and the IAEA Secretariat to decide upon the scope and type of assistance required.

States are responsible for developing arrangements for requesting and receiving international assistance. Such arrangements should be coordinated, integrated and documented in the State's emergency response plans, and should be included in the State's overall national emergency preparedness and response framework.

States should strive to achieve compatible arrangements to ensure effective international assistance.

Once a State has requested assistance, the following actions are envisaged to be taken by the requesting State, where applicable:

- Participating in the development of the Assistance Action Plan (AAP) for the requested assistance and finalizing the proposed AAP for implementation in a timely manner;
- The overall direction, control, coordination and supervision of any assistance within its territory;
- Ensuring that the implementation of the AAP will be conducted in a safe and secure manner;
- Providing, to the extent of its capabilities, local facilities and services for the proper and effective provision of the assistance;
- Ensuring the protection of personnel, equipment and materials4 brought into its territory by or on behalf of the assisting party for such purpose;
- Providing, as necessary, technical, financial, diplomatic, organizational and logistical support as designated in the AAP for the requested assistance;
- Declaring the termination of assistance in consultation with all parties to the AAP;
- Providing relevant medium and long term information related to the status of the situation addressed during the Assistance Mission (e.g. follow-up).

Assisting States

Identified Competent Authorities and permanent mission to the IAEA should be authorized to offer and approve the provision of requested assistance.

States that have registered their NACs in RANET are responsible for:

- Designating NAC coordinator(s).
- Ensuring that the National Warning Point (NWP) and the Competent Authorities have appropriate procedures for responding to a request for assistance.
- Maintaining NAC resources registered in RANET.
- Conducting periodic reviews on continued availability of NAC resources, and updating registration at a minimum frequency of once every two years, or if resources or areas of expertise undergo significant changes.
- Participating, as appropriate, in IAEA meetings concerning RANET.
- Ensuring awareness of RANET within their national structures and promoting its use and development.
- Placing NAC resources on standby, if available, to provide the requested assistance.
- Coordinating the assistance with their ministry of foreign affairs/permanent mission to the IAEA.
- Identifying the individual(s) who have the delegated responsibility to sign the AAP in a timely manner.
- Identifying any terms, especially financial, for the provision of assistance in the AAP.
- Being prepared to participate in the development and approval of the AAP in a timely manner. This includes the identification of an Assistance Mission Leader, as appropriate, in coordination with all parties.
- Identifying and activating/deploying NACs.
- Providing on-scene and/or externally based assistance according to the AAP.
- Ensuring coordination with the requesting State, assisting State(s), the IAEA Secretariat and any deployed or externally based assistance.
- Demobilizing NAC resources upon termination.

The IAEA Secretariat

Upon receiving a request for assistance, the IAEA Secretariat, through its Incident and Emergency System (IES), appoints an Assistance Officer.

The Assistance Officer is responsible for:

- Evaluating the assistance request to determine if the required capabilities are registered in RANET;
- Determining if the assistance requested is feasible and can be provided by countries identified by the IAEA Secretariat (in cases where the requested capabilities are not registered in RANET);
- Recommending the deployment of an Assessment Mission to the requesting State to further assess the situation;
- Recommending specific RANET capabilities, if appropriate;
- Alerting appropriate NWP(s) and requesting coordination with the Competent Authorities/NAC coordinator(s);
- Receiving and, as appropriate, reviewing offers of assistance and forwarding the offers to the requesting State;
- Ensuring timely development of an AAP, including identification of an Assistance Mission Leader, as appropriate, in coordination with all parties;
- Liaising with the requesting State and States offering assistance to reach agreement on the AAP and coordinating any proposed changes;
- Establishing and maintaining communication links with the Assistance Mission and States providing assistance, as appropriate;
- Providing financial, organizational and logistical support, as appropriate;
- Declaring the official termination of an Assistance Mission;
- Establishing follow-up activities if deemed appropriate.
- The IAEA Secretariat has the following additional responsibilities for maintaining RANET.

- Reviewing NACs and other resources submitted for registration in RANET;
- Documenting and registering all endorsed NACs and other resources of States;
- Maintaining the RANET database of registered capabilities, resources and expertise;
- Promoting RANET and reporting annually on RANET's status and activities;
- Conducting RANET workshops and meetings;
- Biennially requesting certification of continued NAC resource availability;
- Facilitating the conduct of exercises, where practicable within existing national, regional and international exercise regimes;
- Gathering and reviewing information on registered NACs, for example through liaising with the NAC coordinator, observation of NACs during national or international exercises, participation in Assistance Missions and/or the conduct of RANET Review Missions;
- Facilitating the exchange of lessons (within RANET) identified in Assistance Missions.

Concept of operations

RANET is a network of States that are capable and willing to provide, upon request, specialized assistance by appropriately trained, equipped and qualified personnel with the ability to respond in a timely and effective manner to nuclear or radiological emergencies, regardless of their origin.

If a State needs assistance in the event of a nuclear or radiological emergency, whether or not such an event originates on its territory or is under its jurisdiction or control, it may request assistance from or through the IAEA.

The State's permanent mission to the IAEA, or Competent Authority, is the Government representative that is expected to request assistance. To facilitate the effective provision of assistance, it is expected that a State will request assistance through one of the following communication channels, listed by preference:

1) Submitting the Request for Assistance (RFA) form on the IAEA's Unified System for Information Exchange in Incidents and Emergencies (USIE);
2) Fax to the IEC through the 24/7 communication channel;
3) Telephone to the IEC through the 24/7 line.

The request for assistance needs to include the scope and type of assistance required as follows:

(a) Information about the nuclear or radiological emergency: location, time of its occurrence (UTC and local time), name and full address of organization in charge of response actions, and name and contact details of person assigned to liaise with the IAEA Secretariat;

(b) Type(s) of emergency assistance required: nuclear installation assessment and advice, source search and recovery, radiation survey, sampling and analysis, assessment and advice, decontamination, medical support, dose assessment.

Operations

Upon receiving an official assistance request, the IAEA's Incident and Emergency Centre (IEC), according to the IAEA's IES, becomes the focal point for the facilitation and coordination of international assistance. The request for assistance is reviewed by the ERM to determine if the assistance being requested is for a nuclear or radiological emergency, and an appropriate Assistance Officer (or team) is appointed.

The Assistance Officer reviews the request to determine if the requested expertise and capabilities are registered in RANET.

If the requested capabilities are not registered in RANET, the Assistance Officer may contact States who have previously demonstrated the requested capabilities in emergency exercises/response. In complex situations and if the scope of assistance cannot be clarified, the Assistance Officer may recommend deployment of an Assessment Mission to the requesting

State to further assess the needs for assistance. The Assessment Mission, if deployed, will evaluate the situation, provide immediate advice as needed, and recommend activation of appropriate assistance capabilities.

The IAEA Assistance Mission with the involvement of RANET will be tailored to the specific situation; e.g. it may include deployment of assets as well as provision of advice or assistance from an external base.

If the activation of NAC resources is recommended, the Assistance Officer will alert the appropriate National Warning Point(s) and request coordination with relevant Competent Authorities/NAC coordinator(s). The Competent Authorities/NAC coordinator(s) will inform the Assistance Officer regarding the availability of their resources for assistance and, if available, an Offer of Assistance (OFA) will be submitted via USIE, email or fax. This concept is outlined in Fig. 28.

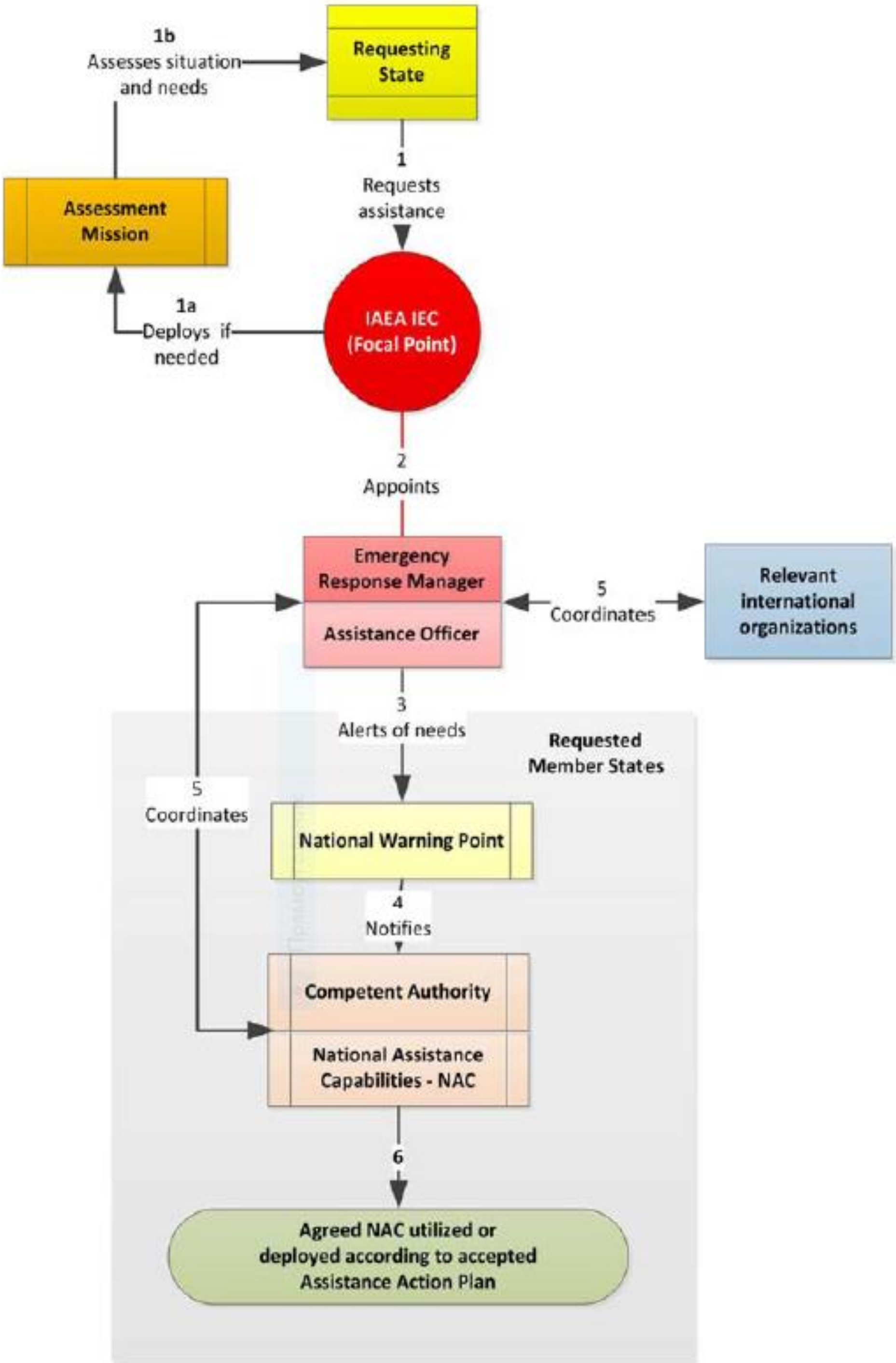

Fig. 28. Outline of the RANET concept

The IAEA Secretariat, taking into account any confidentiality requirements associated with the assistance request(s), only shares the Request for Assistance (RFA) with States that have the registered NACs and/or were identified in the RFA by the requesting State. The sharing of the RFA(s) is carried out on USIE to enable prompt sharing of information between relevant counterparts.

The Assistance Officer will then liaise with the requesting State and offering States, as necessary, to determine which assistance is accepted and to establish the exact nature of the Assistance Mission and development of the AAP.

In circumstances where the IAEA Secretariat requests NAC resource assistance in support of its own operations (e.g. within the implementation of the Agency's role in assessment and prognosis), the same process of alerting the appropriate National

Warning Point(s) and requesting assistance with relevant Competent Authorities/NAC coordinator(s) will be followed

A State sends request for assistance to the IAEA's IEC (Focal Point) (1). The Emergency Response Manager (ERM) determines the type of assistance required. The ERM appoints Assistant Officer (or team) accordingly. (2). If needed, an IAEA Assessment Mission (1a) is deployed to assess assistance needs (1b). If activation of RANET assets is deemed necessary, Assistance Officer alerts National Warning Point(s) (3), which notifies appropriate Competent Authorities (4). Competent Authorities/NAC coordinator(s) then coordinate provision of assistance with Assistance Officer (5). If appropriate, Assistance Officer also coordinates provision of assistance with relevant international organization(s). Agreed assistance capabilities are utilized or deployed according to the accepted Assistance Action Plan (6).

IAEA Assistance Mission

An Assistance Mission is performed by a group of qualified experts and can be in the form of a Field Assistance Team (FAT), an External Based Support (EBS) or a Joint Assistance Team (JAT) comprising a combination of FAT and/or EBS to provide advice, assessment, medical support, monitoring or other specialized assistance following nuclear or radiological emergencies, regardless of their origin.

The findings from an Assessment Mission, if previously deployed, are incorporated into the Assistance Mission.

Depending on the objectives and scope of the Assistance Mission, the exact nature and title of the mission will be specified in the Assistance Action Plan (AAP) developed and agreed upon for that mission.

Team Leaders (Assistance Mission Leader, FAT Leader(s) and/or EBS Leader(s)) will be identified and agreed upon by all parties to the AAP. The Team Leader(s) will be responsible for all assistance activities and ensure(s) coordination with the requesting State, assisting State(s), the IAEA Secretariat and any External Based Support8.

Where an Assistance Mission is implemented as a JAT, the JAT Command, composed of all FAT Leaders, including an IAEA Secretariat representative, manages all on-scene JAT assistance and ensures coordination with the requesting and assisting State(s), any External Based Support(s) and the IAEA Secretariat as appropriate.

The identified Team Leader(s) must have the necessary technical and managerial experience to support and assist the requesting State. The Team Leader(s) also must have the expertise to oversee the operation and the ability to communicate within the given command structure. The person has to:

- Lead and manage the Assistance Mission, FAT or EBS and ensure that all technical tasks are performed according to the AAP;
- Ensure the safety and security of the team members;
- Provide the support needed to achieve the mission's objectives;
- Liaise with and regularly contact the respective Team Leader(s), identified State representatives and the IAEA Secretariat as appropriate.

NAC activation

NAC activation will be in accordance with the AAP for an Assistance Mission.

Upon activation, the Team Leader will initiate the development of a mission plan to ensure that the team is able to perform its assigned AAP tasks. Mission planning needs to identify/address:

- The problem;
- The assistance task(s) assigned;
- Known constraints (e.g. safety, security, logistical);
- Equipment needs;
- Personnel needs;
- Other resources (FAT and/or EBS);
- Resource support needs (e.g. aircraft, vehicles, base location, power).

In the case of a JAT, all mission plans are incorporated into the overall JAT mission plan.

Mission planning is a process that will need to continue throughout the mission until all assigned tasks have been completed.

The concept of an Assistance Mission is outlined in Fig. 29.

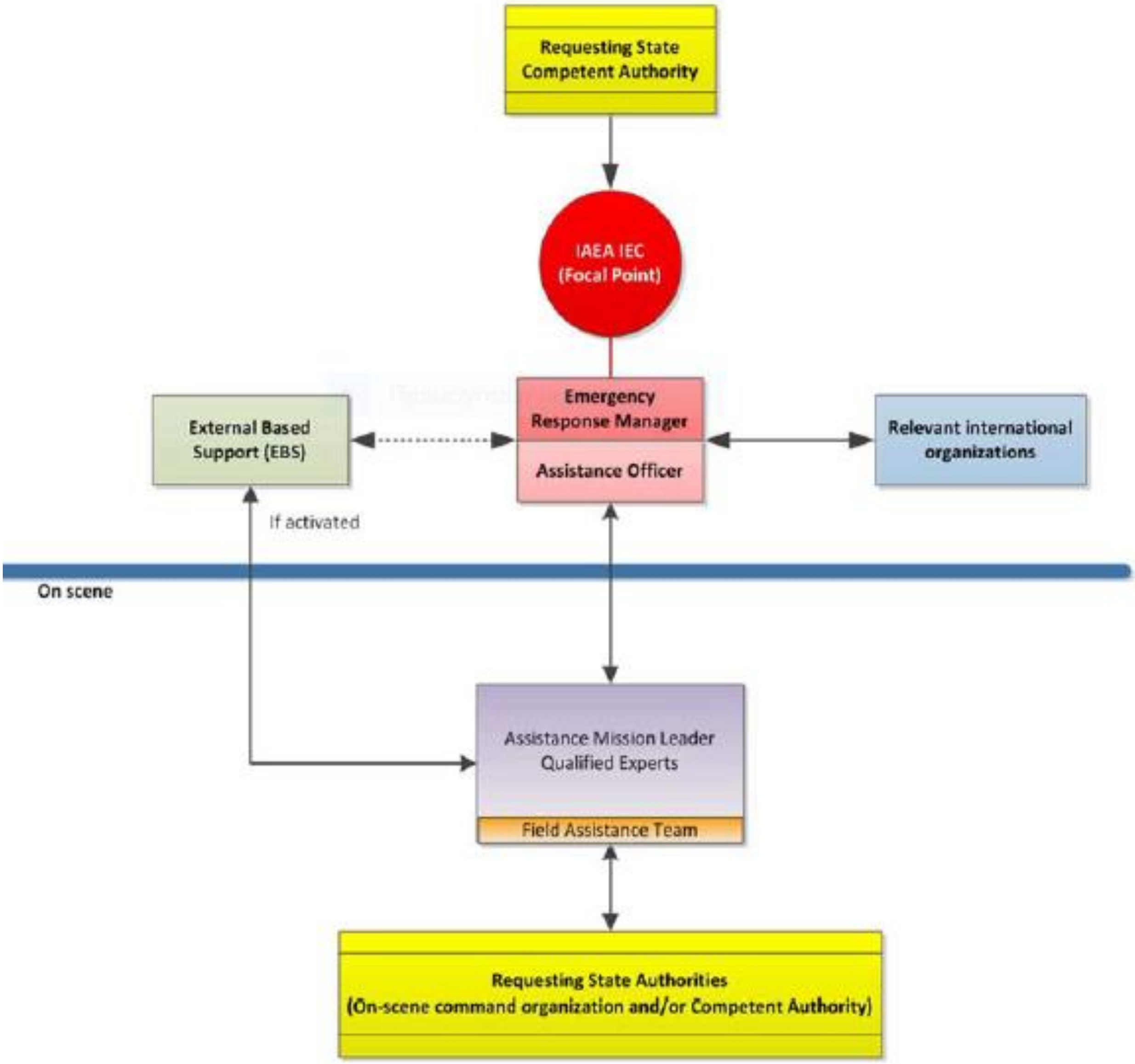

Fig. 29. The concept of an IAEA Assistance Mission

Field Assistance Team (FAT)

A FAT is a group of technically qualified and equipped experts deployed to provide the requested assistance.

A FAT Leader will be identified in the AAP.

External Based Support (EBS)

External Based Support provides any reach-back or off-scene capabilities to a requesting State, FAT or JAT. Such support can be expert advice on assessment, monitoring, analytical methods, medical support or other specialized emergency response function. This support is not deployed to the event scene but is provided from another location, such as the assisting party offices, laboratories or other locations.

An EBS Leader will be identified for each activated EBS.

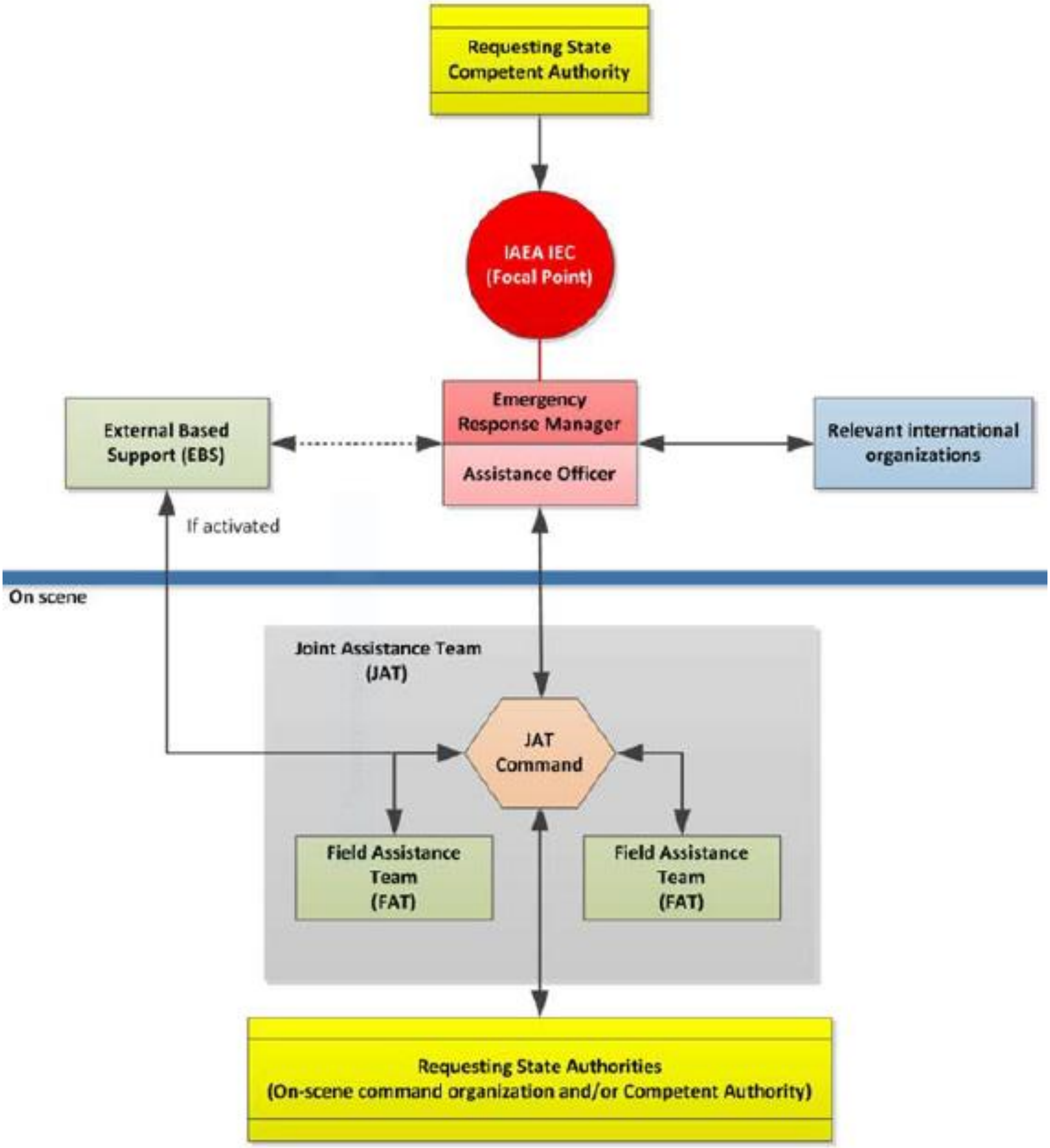

Fig. 30. The concept of an Assistance Mission as a Joint Assistance Team

Joint Assistance Team (JAT)

In more complex situations, a Joint Assistance Team is formed. The exact nature of the JAT will be specified in the AAP developed and agreed upon for that mission. The JAT consists of all deployed FAT(s) and/or EBS(s).

The coordination of the RANET assistance on the scene is performed by the JAT Command, which is composed of all FAT Leaders. The Assistance Mission Leader, who is identified and agreed upon by all parties to the AAP, performs the role of Chairperson of the JAT Command[9]. The IAEA Secretariat assists the Assistance Mission Leader in the fulfilment of duties, including technical support to deployed assets and liaison with local counterparts, and, if appropriate, provides IAEA Secretariat media expertise in support of the mission. The concept of an Assistance Mission as a Joint Assistance Team is outlined in Fig. 30.

Field operational safety and security

The Assistance Mission Leader or the JAT Command implements the activities set by the AAP. They are responsible to ensure that all activities are performed in a safe and secure manner by following procedures, which at a minimum meet the appropriate IAEA safety standards and United Nations Department of Safety and Security (UNDSS) guidance.

In an emergency response, priority will be placed on the safety and security of personnel and members of the public. Operations and/or activities in conditions that are unsafe or not secure, or possibly unsafe or not secure, will not be conducted. Where any such situations are identified, the JAT Command or the Assistance Mission Leader will coordinate with the appropriate authorities and entities to identify an acceptable, safe/secure solution for the conduct of the identified activities.

Assistance termination

The requesting State or any of the assisting parties may at any time, after appropriate consultations and by notification in writing, request the termination of assistance received or provided. Once such a request has been made, the involved parties consult to make arrangements for the proper conclusion of the assistance.

The termination of assistance could be through any of the following:

- All AAP tasks have been certified as completed as per the AAP.
- The requesting State may declare at any time the end of the requested assistance.
- An assisting State may terminate or withdraw its assistance at any time.
- The IAEA may declare at any time the end of assistance due to failure to resolve conditions or practices that are unsafe or not secure, or the failure of the requesting State to comply with the AAP.
- Partial demobilization of resources may occur as the individual AAP tasks are completed.

Upon termination of the assistance, the NAC resources will be demobilized.

Assistance reports

Upon completion of any assistance, up to two reports may be required: the After Action Assistance Report and the Assistance Report. For smaller missions, the IAEA Secretariat may determine, in consultation with the requesting State, that only an Assistance Report may be required.

After Action Assistance Report

The Assistance Mission Leader or the JAT Chairperson and the responsible person(s) for the EBS prepare the After Action Assistance Report (AAAR). The AAAR will contain a description of the event, actions taken, recommendations and conclusions. In most instances, the AAAR will be submitted within one week of the termination of the assistance. However, the one week deadline may be extended in major emergencies as agreed by all parties. The AAAR will be submitted to the IAEA Secretariat for distribution to the requesting State and the States providing assistance.

The AAAR will be released upon agreement by the involved parties and the IAEA Secretariat. The AAAR will be distributed to all parties to the AAP.

Assistance Report

Within 60 days, the IAEA Secretariat will produce a final Assistance Report in coordination with the requesting State and all involved parties to fully describe the event's history, response actions taken, resolution of the situation, recommendations for future actions (if any) and lessons identified. In cases where the assistance requested and provided was limited (for instance, no Assistance Mission was deployed, only EBS assistance was required), and where it has been determined that a less comprehensive report is sufficient, the IAEA Secretariat may agree to a shorter timeframe for the issuance of the report to all parties involved in the Assistance Mission.

The Assistance Report will be distributed only to the requesting State and the assisting parties (States, international organizations), unless otherwise agreed. Upon agreement by the involved parties and the IAEA Secretariat, the Assistance Report will be distributed to all parties to the AAP.

The IAEA Secretariat will, with the consent of the involved parties, make the Assistance Report available, in confidence, to other members of RANET. The shared version of the Assistance Report may be modified to remove any private or sensitive material as may be required.

The IAEA Secretariat may, with the consent of the involved parties, make a public version of the Assistance Report available.

Financial arrangements

The financial principles of the response operations to a nuclear accident or radiological emergency must be in accordance with Article 7 of the Assistance Convention, and it is expected that these principles will also be applied in the response to other nuclear or radiological emergencies. States offering assistance need to consider any financial requirements in advance and specify the financial requirements in the offer of assistance, as appropriate, taking into account the considerations in Article 7 of the Assistance Convention.

Some financial support for RANET assistance activities may be provided through the IAEA's regular budget or from other IAEA resources. The IAEA may cover the expenses for the initial mobilization and deployment of the Assessment and/or Assistance Mission. If the IAEA cannot cover these initial expenses (for reasons of timing, for example), the States may cover the expenses, which may be reimbursed at a later stage.

States are also responsible for maintaining insurance, or otherwise, without prejudice to Article 10 of the Assistance Convention, assume financial liability, for the responders and the equipment that they deploy.

The IAEA assumes no liability for personnel or equipment of States providing assistance.

National assistance capabilities

Article 2, Paragraph 4 of the Assistance Convention states: «States Parties shall, within the limits of their capabilities, identify and notify the Agency of experts, equipment and materials which could be made available for the provision of assistance to other States Parties in the event of a nuclear accident or radiological emergency as well as the terms, especially financial, under which such assistance could be provided».

States Parties may meet this obligation under the Assistance Convention by identifying NACs that could be made available to assist another State and registering them in RANET. NACs consist of qualified experts/expertise, equipment, materials and other resources that can be activated to provide assistance either by deployment to the event scene or from an external base, such as assisting State offices, hospitals, laboratories or other locations. States which register their NACs in RANET may also register additional resources that could be made available to another State.

NACs are registered only through the relevant Competent Authority. Capabilities and resources of private entities being registered in RANET need to be certified and registered through this Competent Authority.

Registration of capabilities in RANET does not automatically obligate the registered State to provide assistance. When requested, the relevant Competent Authority will decide on the availability of its assets and its ability to assist.

States Parties are obliged, and other States encouraged, to identify and report to the IAEA, within the limits of their capabilities, the resources which could be made available for the provision of assistance to a requesting State, as well as the terms under which these resources may be obtained (e.g. through donation, loan or procurement).

States that are not Party to the Assistance Convention are encouraged to identify NACs and register them in RANET.

NAC activities and functional areas

To ensure effective assistance, whether by advice, external based support, and/or deployed assets, NACs may be called upon to, inter alia:

- Assess, advise on and assist in the on-site response activities to mitigate the impact of nuclear or radiological emergencies;
- Search and recover radioactive sources;
- Detect, locate, identify and characterize radioactive material and contamination;
- Assess and evaluate radiological consequences;
- Provide advanced nuclear analyses;
- Provide modelling and prognosis capability;
- Provide technical advice and recommendations;
- Initiate stabilization activities, including, where appropriate, decontamination;
- Provide medical advice and/or consultation, medical assistance as necessary and advice on public health;
- Provide sampling, measurements and analysis.

The technical guidelines in Section 6 define the basis for the development of compatible and integrated NAC resources. Guidelines are given for the following NAC Functional Areas:

- Nuclear Installation Assessment and Advice (NAA);
- Source Search and Recovery (SSR);
- Radiation Survey (RS);
- Sampling and Analysis (SA);
- Radiological Assessment and Advice (RAA);
- Decontamination (DE);
- Medical Support (MS);
- Dose Assessment (DA).

The relevant Competent Authorities needs to review the guidelines to help identify the available expertise and resources that they possess as NACs.

NAC expertise, resources and preparedness

States registering in RANET identify and register the expertise that they possess as part of their NACs, which could be made available to provide assistance following a nuclear or radiological emergency, regardless of its origin. The Competent Authority ensures that the identified expert(s) is/are suitably qualified and experienced, along with appropriate NAC preparedness, so as to be able to provide international assistance as part of a field deployment and/or EBS.

NAC expertise and resources

Examples of the expertise may be grouped into, but are not limited to, the following:

- Nuclear installation safety;

- Radiation safety;
- Measurement techniques;
- Internal and external dosimetry;
- Radiation medicine;
- Evaluation and assessment;
- Operation of specialized technology;
- Scene management;
- Advanced nuclear analyses.

The NAC expertise is complemented by suitable equipment and materials that are necessary for the delivery of the requested assistance. It is recommended that these resources be identified and registered as part of the NACs.

States are also encouraged to identify and register the resources that they may be able to provide to a requesting State, as well as the terms under which these resources may be obtained (e.g. through donation, loan or procurement).

These may include, but are not limited to:

- Radiation survey instruments;
- Personal dosimetry (active and passive);
- Medical equipment and supplies;
- Measurement systems;
- Personal protective equipment;
- Electrical generators and supplies;
- Cooling and purification systems;
- Criticality control materials;
- Ventilation systems;
- Specialized resources (e.g. robotics, aircraft, shielding);
- General supplies to support field activities.

Where States register resources that may be offered to other States, they are encouraged to provide the necessary details, specifications, method of transportation and estimated quantities of these resources, so that a requesting State can assess the suitability of these resources depending on the nature of the event and the resources that may be required. This additional information may be provided as attachments to the RANET registration form or, once registered, entered directly into the RANET database.

NAC preparedness

The organization(s) providing assistance need(s) to ensure that all the deployable personnel are/have:

- Fit for duty;
- Valid passports;
- Current immunizations;
- Medically approved physical condition for field operations;
- Pre-approved travel orders (if required by the Competent Authorities);
- Pertinent responder information (blood type, emergency contact, allergies, languages spoken, dosimetry records);
- A signed statement indicating willingness to respond.

The assisting organization is expected to provide, if necessary (indicative list):

- Communications equipment;
- Electrical generators to operate the field equipment;
- Food and water for the first 72 hours;
- Personal protective equipment for the first 72 hours;
- Tents, sleeping bags and clothing for bad weather;
- Devices with the capability to record still and video images.

The Competent Authority is also responsible for ensuring that the organizations providing assistance have quality control programmes in place (e.g. documented procedures and instructions for all registered capabilities under RANET). All procedures, manuals and reference data relevant to the work of the NACs need to be maintained up to date and be readily available for use. The following is an indicative list of procedures to be maintained as part of the preparedness programme for the NACs:

- Notification and recall rosters and procedures — to include the process of notification and the telephone/pager numbers of the potential responder personnel;
- Personnel and equipment deployment procedures — to include administrative approvals, financing of travel, insurance, the process of transporting personnel, and packaging of the equipment and its transportation to the assistance location;
- List of deployable equipment — to include shipping information for hazardous material, customs forms (ATA Carnet) and other security related requirements as necessary;
- Procedures for all field response operations — to include the processes that each deployable asset will follow to perform the assigned tasks;
- Emergency Operation Document/Home Team Procedures (however named) for field deployment — to include the process of coordinating and supporting the deployment both logistically and technically13;
- Redeployment of personnel and equipment procedures — to include the process of coordinating the transportation of personnel and equipment from the event site to their home base;
- Procedures to ensure adequate protection of the personnel against ionizing radiation.

The assisting organizations and Competent Authority are also expected to identify, in advance, suitable processes through which the NACs can promptly ship equipment and resources between States. NACs that have registered as FAT and/or that have registered resources that could be deployed to provide assistance are encouraged to obtain an ATA Carnet for all resources that may be deployed. An ATA Carnet is an international customs and export-import document that is used to clear customs, in ATA Carnet participating countries, without paying duties and import taxes on the deployed resources. The ATA Carnet system is administered by the World Customs Organization and is needed to export/import equipment when leaving and returning to the assisting State as well as entering and leaving the requesting State.

A list of documentation examples is provided in Appendix C, and examples of pre-deployment tasks are provided in Appendix G.

NAC readiness

Each State which is registered in RANET is responsible for ensuring that NAC responding personnel are qualified, trained and equipped to perform the functions for which they have registered.

NACs must use appropriate methods and procedures for the registered competencies, and, where possible, methods selected are to be consistent with the guidance in IAEA publications and the International Organization for Standardization.

When possible and appropriate, NACs will participate in international exercises such as ConvEx or intercomparison exercises.

Competent Authorities will provide to the IAEA Secretariat information on the effectiveness of the RANET network and on recommendations for improvements. The IAEA Secretariat will distribute this information with envisaged corrective actions to all States registered in RANET and to Assistance Officers within the IAEA's IES.

NAC registration

Prerequisites for registration

The following are prerequisites for registration in RANET:

- The Competent Authority authorized to make, and receive requests for and to accept, offers of assistance must submit a completed registration form;

- NAC maintenance, preparedness and response are the responsibility of the State, in accordance with this publication.

Registration

The applying Competent Authority provides the following information:

- An application signed by the Competent Authority authorized to make and receive requests for, and to accept offers of, assistance;
- Information on National Assistance Capabilities (including description of the expertise and resources) in accordance with the technical guidelines in Section 6;
- A list of the organizations contributing to the NACs, including contact details, so that the IAEA may recognize their contribution to RANET.

Details of the RANET registration and instructions on how to register are presented in Appendix A.

The initial application for the registration needs to be sent to the IAEA Secretariat through the foreign ministry or the permanent mission.

Registration acceptance

The IAEA Secretariat will review the application in accordance with specifications within this document. If it is deemed that the registration meets the specifications, the proposed NACs will be registered in RANET

If the application does not contain sufficient detail on the NACs or is not complete, the IAEA Secretariat will request the Competent Authority to submit the missing information. If it is determined that the NACs proposed for the RANET cannot be registered, a letter stating the reasons will be provided to the applying Competent Authority.

RANET registry database

The IAEA's IEC maintains a database of RANET registered NACs (expertise, equipment, materials and/or resources) that could be provided to requesting States and the IAEA Secretariat. The information related to the registered NACs is available through the USIE web site, with due regard to the principle of protection of sensitive information.

Registration update

Once registered, States have the responsibility to notify the IAEA's IEC if NAC resources and areas of expertise undergo significant changes or become unavailable. Also, any changes regarding the NAC coordinator are to be reported in a timely manner. These changes may be done directly online through the RANET database on USIE.

A State that wishes to discontinue membership in RANET notifies the IAEA's IEC through the official channels.

RANET NAC Review

Periodic reviews of registered RANET NACs may be conducted upon request of the State offering the NACs. The review is to be conducted by an IAEA team that may include experts from other States registered in RANET. The review team is endorsed by the State requesting the review.

The objectives of the RANET NAC reviews are to:

- Ensure that the registered capabilities can be effectively and efficiently utilized and performed as cited in the registration;
- Gather relevant information regarding the NACs so as to best utilize available RANET assets following a request for assistance;
- Review the current level of preparedness to provide international assistance;
- Harmonize international assistance by identifying and sharing examples of good practice;
- Identify improvements for States to enhance the NACs and Competent Authority preparedness to provide international assistance.

In addition, the RANET NAC Review may help States to identify other NAC resources that they may register in RANET.

The review may be performed through observation of the NACs during the conduct of exercises, the provision of assistance, the conduct of RANET Review Missions or a combination thereof. RANET Review Missions may be requested by States that have registered in RANET or are preparing the final stages of registration.

In circumstances where the review determines that a registered NAC may not be at a suitable level to provide international assistance, the NAC will be decertified from RANET. The IAEA Secretariat will provide the Competent Authority with recommendations and required remedial actions, which, if implemented, will ensure that the NAC can be recertified. It is the responsibility of the relevant organization(s) and the Competent Authorities to implement any remedial actions, including the financing of such actions.

Assistance Action Plan

An Assistance Action Plan (AAP) is required for an Assistance Mission, Joint Assistance Team (JAT) and External Based Support (EBS). An AAP is not required for the provision of information or advice.

An Assistance Action Plan (AAP) for the requested assistance will be developed by the Assistance Officer (or team) in coordination with the Emergency Response Manager (ERM), the Assistance Mission Leader and the Competent Authorities/NAC coordinator(s) of the requesting State and the assisting State(s). The AAP will be agreed upon by all involved parties.

This plan will specify the assistance needed and state whether the assistance will be deployed and/or provided from an external base. The AAP includes all technical, financial, diplomatic, organizational and logistical aspects of the assistance to be provided and is signed by all participating parties, (i.e. requesting State, assisting State(s), IAEA Secretariat and, as appropriate, relevant international organizations).

When developing the AAP, specialized techniques, existing agreements and arrangements/collaboration between the States may be considered in the composition of the Assistance Mission.

The AAP will also specify the composition of the team(s) performing the mission, including the Assistance Mission Leader, EBS Leader and FAT Team Leaders.

The Assistance Mission Leader will be nominated by the IAEA's IEC before deployment, based on agreement among all assisting parties, taking into account the mission objectives and the composition of the team(s).

Upon acceptance of the AAP by the requesting State, the assisting States' Competent Authorities/NAC coordinators will be notified, and activation of NAC resources will be requested. Changes to the AAP must be coordinated with all parties before the changes are implemented.

Details of the AAP are described in Section 5, and an example of an AAP is presented in EPR–RANET 2018 Emergency Preparedness and Response, IAEA Response and Assistance Network Appendix B.

Main sections of AAP

Cover page will include:

- A title, indicating the name of the State requesting assistance;
- A subtitle, describing briefly the event for which assistance was requested;
- The date on which the plan was prepared;
- The date on which the plan became effective;
- The version number.

Relevant officials page

This page will include:

- The name and signature of the IAEA official;
- The names, State(s), organization(s) and signature(s) of the assisting State official(s) who agreed to the terms of the AAP;

- The name(s), organization(s) and signature(s) of the representative(s) of the assisting international organization(s) who agreed to the terms of the AAP;
- The name, organization and signature of the requesting State's official who accepted the AAP.

Background

This section will include:

- The names of the State and organization requesting assistance;
- The date on which the IAEA's IEC received the request;
- The date, location and type of event for which assistance was requested;
- A description of what is known to date on the situation;
- The requesting State's status under the Assistance Convention (i.e. Party or non¬Party).

Objective and scope

This section will include:

- A description of, and justification for, the type of assistance to be rendered;
- The expected starting and ending dates of the assistance;
- The scope of the assistance;
- Based on initial information, a potential list of activities to be performed; actual tasks, activities and priorities will be determined by on-scene assessments and continued updating of information.

Responsibilities

This section will include the respective responsibilities of the requesting State, the Assistance Mission team, the Assistance Mission Leader, the assisting party(ies) and the IAEA's IEC, as detailed in this publication.

The requesting State will, where applicable:

- Ensure that the AAP will be implemented in a safe and secure manner;
- Provide, as necessary, technical, financial, diplomatic, organizational and logistical support as designated in the AAP for the requested assistance;
- Grant the Assistance Mission team the necessary privileges, immunities and facilities to perform the necessary assistance functions;
- Grant the Assistance Mission team unfettered access to all persons, locations, facilities and information necessary for the successful implementation of the AAP.

The Assistance Mission team will:

- Accomplish the objectives and conduct the activities (overall work plan) set by the AAP;
- Provide the IAEA Secretariat with an authoritative and factual overview of the emergency and make recommendations for any further action(s).

The Assistance Mission Leader will:

- Maintain operational supervision over the Assistance Mission team and the equipment provided by or on behalf of the Assistance Mission team;
- Ensure that all activities are performed in a safe manner;
- Prepare an After Action Assistance Report within one week after completion of assistance.

The assisting party(ies) will:

- Provide the requested assistance, through the IAEA, to the requesting State. The IAEA's IEC will:
- Prepare an Assistance Report in coordination with all involved parties;
- Serve as the focal point for the provision of the international assistance outlined in this AAP, providing the necessary coordination, administration and support to all parties.

Other sections

The AAP will also have separate sections covering the following:

- Confidentiality of information and materials related to assistance;
- Public information;
- Field operational safety and security;
- Financial arrangements;
- Privileges and immunities;
- Assistance termination;
- Overall work plan reflecting an on-scene assessment to include a list of activities and proposed dates of when each activity will be conducted;
- Annex I: Assistance Mission Team Composition;
- Annex II: Relevant Contact Details.

Annex I includes details of the assisting State Team(s) and the capabilities and resources being utilized during the Assistance Mission. This includes names of the States and organizations providing assistance; and the names of (any) international organizations providing assistance. Annex II includes the names, functions, States and organizations of persons assigned to the Assistance Mission teams.

ANALYSING EMERGENCY AND EMERGENCY RESPONSE

Overview of the past nuclear emergencies

Requirement 19 «Analysing the nuclear or radiological emergency and the emergency response» of GSR Part 7 states:

«The government shall ensure that the nuclear or radiological emergency and the emergency response are analysed in order to identify actions to be taken to avoid other emergencies and to improve emergency arrangements.

Arrangements shall be made to document, protect and preserve, in an emergency response, to the extent practicable, data and information important for an analysis of the nuclear or radiological emergency and the emergency response. Arrangements shall be made to undertake a timely and comprehensive analysis of the nuclear or radiological emergency and the emergency response with the involvement of interested parties. These arrangements shall give due consideration to the need for making contributions to relevant internationally coordinated analyses and for sharing the findings of the analysis with relevant response organizations. The analysis shall give due consideration to:

a) The reconstruction of the circumstances of the emergency;

b) The root causes of the emergency;

c) Regulatory controls including regulations and regulatory oversight;

d) General implications for safety, including the possible involvement of other sources or devices (including those in other States);

e) General implications for nuclear security, as appropriate;

f) Necessary improvements to emergency arrangements;

g) Necessary improvements to regulatory control.

Arrangements shall be made to enable comprehensive interviews on the circumstances of the nuclear or radiological emergency to be conducted with those involved.

Arrangements shall be made to acquire (e.g. from the IAEA, from another State or from the manufacturer of relevant equipment) the expertise necessary to conduct an analysis of the circumstances of the nuclear or radiological emergency.

Arrangements shall be made to take actions promptly on the basis of an analysis to avoid other emergencies, including provision of information to other operating organizations, as relevant, or to other States, directly or through the IAEA».

An emergency is defined in the IAEA Glossary as «a non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human health and safety, quality of life, property or the environment. This includes nuclear and radiological emergencies and conventional emergencies such as fires, release of hazardous chemicals, storms or earthquakes. It includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard».

Several nuclear emergencies have occurred, most notably, the Windscale fire in 1957, the Three Mile Island accident in 1979, the Chernobyl accident in 1986, the Sarov accident in 1997, the Tokaimura accident in 1999 and Fukushima accident in 2011. Radiological emergencies have occurred throughout the world, and when invited by the country concerned, the IAEA has undertaken comprehensive reviews of the events, the purpose of which is to compile information about the causes of the accidents, the subsequent emergency response including medical management, dose reconstruction, public communication, etc., so that any lessons can be shared with national authorities and regulatory organizations, emergency planners and a broad range of specialists, including physicists, technicians and medical specialists, and persons responsible for radiation protection. It is appropriate to analyze the findings of these and other reports on the response to radiation emergencies in order to consolidate these lessons.

Since 1945 more than 215 nuclear and radiological emergencies and incidents had occurred. The most characteristic of them from the point of view of learning lessons will be briefly discussed in this tutorial.

Considering nuclear and radiological emergencies, drawing conclusions on how to prevent them and deal with their consequences, it is very useful to study the experience of responding to the elimination of the consequences of man-made and natural non-radiation accidents. Examples of such studies include:

- The Bhopal, India Hazardous materials release in 1984
- Hurricanes Katrina and Rita in 2005
- London bombings in 2005 and many others.

Among topics for study about response on non-radiological emergencies the main are:

- Emergency assessment
- Population protection
- Hazard operations
- Incident management
- Public health response strategy
- Managing the response
- Environmental monitoring and assessments and others.

The Three mile island (TMI) nuclear power plant accident

As with most reactors, the TMI reactor had three barriers that must fail in order for there to be a major release of radioactive material resulting in public exposure. There are the fuel pins (first barrier), that form the core where the nuclear reaction takes place. The core is surrounded by a cooling system (second barrier), that is intended to always keep the core covered with water. The cooling system includes pumps that automatically replace any water that may be lost. The core and cooling system are within a very large and strong structure, called the containment (third barrier), which is intended to prevent any radioactive material released from the core and cooling system from being released into the atmosphere. The core must always be kept covered with water, otherwise it will heat up and pins holding the fuel can begin to fail, and the fuel can begin to melt shortly thereafter. If the core did melt, it would release vast amounts of radioactive material into the containment. A melting of the core can also produce conditions that cause the containment to fail unpredictably. The plant was designed to prevent a core from melting, but not designed to prevent a release if the core were to melt.

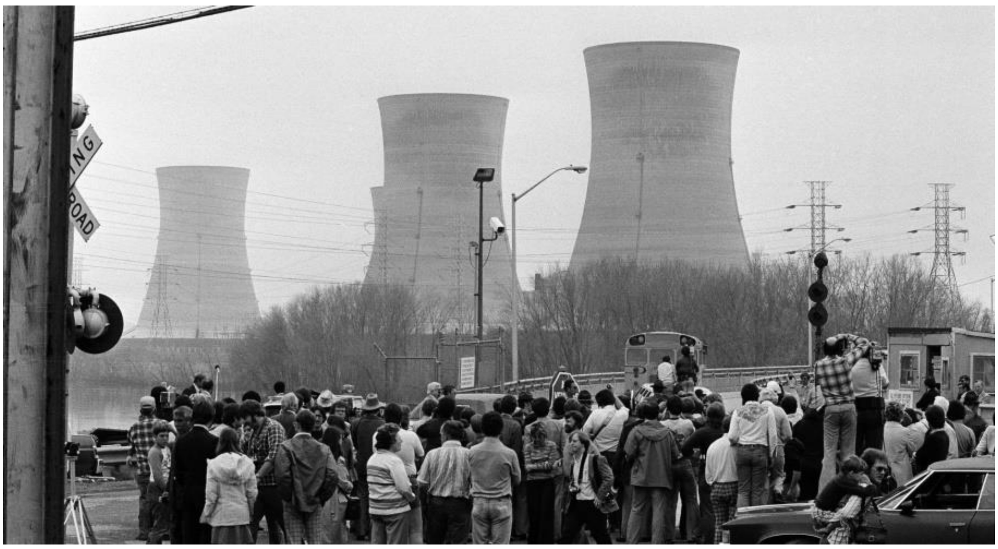

Fig. 31. Three mile island (TMI) nuclear power plant

The accident began on 28 March 1979 at about 04:00 when a pump that fed water to the boiler stopped. This was not a serious event and should have been easily handled by the plant safety system. The safety system operated as intended and shutdown the plant (stopped the nuclear reaction). During the shutdown a valve failed to close allowing water to be released from the cooling system. This loss of water was detected by the safety system which started pumps to inject water to replace what was being lost, and thus ensure the core was kept covered with water. At this point, one instrument in the control room incorrectly showed that there was too much water in the cooling system. The operators, according to their procedures and training, turned off some of the safety system pumps that were replacing the water being lost. Within a few hours the core became uncovered and began to melt and within minutes had released, into the containment, about 40% of all the radioactive material it contained. This was about the same amount of radioactive material that was released into the atmosphere by the Chernobyl accident. The radiation within parts of the plant and containment rapidly increased to 1000 or more times the normal level. However, the operators still failed to understand that the core was not being cooled, even with these indisputable indications of a melted core. After several hours, the operators started a sufficient number of pumps to cover the melted core with water. It took several hours before the mass of melted core cooled. The containment, while not designed for these conditions, remained essentially intact and only a very small fraction of the radioactive material was released into the atmosphere, and consequently the exposure of the public was small. It was several days before it was realized that the danger of a major release had passed. It was several years before it was discovered the core had melted.

As discussed earlier, two days after the core had melted pregnant women and children of preschool age were advised to leave the area within a five mile radius. However, the NRC inquiry found it would have been prudent to recommend precautionary evacuation at about the time the core was being damaged because “the containment building was filling with intensely radioactive gas and vapours, leaving the nearby public protected by only one remaining barrier, the containment, a barrier with a known leak rate that needed only internal pressure to drive the leakage”. In addition, the advisory calling for a few thousand pregnant women and preschool children to evacuate, resulted in entire families evacuating, and it is estimated that over 100,000 people evacuated from areas within 40 kilometres of the plant.

The Chernobyl nuclear power plant accident

The accident occurred at the Chernobyl nuclear power plant in northern Ukraine on 26 April, 1986 and resulted in the release into the atmosphere of a large amounts of radioactivity, primarily radioactive isotopes of Caesium and Iodine. These releases contaminated large areas of Belarus, the Russian Federation and Ukraine, and other countries to a lesser extent. These releases caused sizable populations to receive internal and external radiation doses.

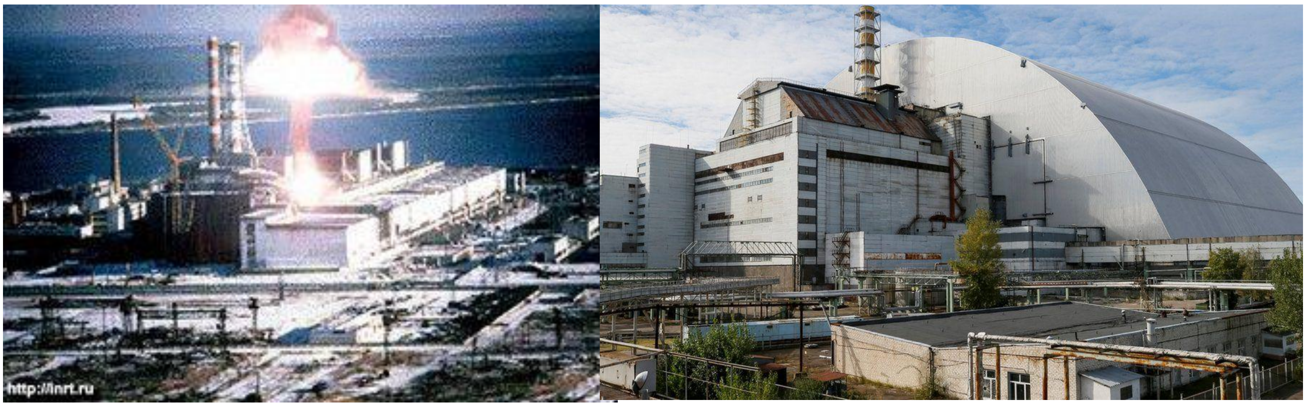

Fig. 32. Chernobyl nuclear power plant

The Chernobyl accident caused the deaths of 30 power plant employees and firemen within a few days or weeks (including 28 deaths that were due to radiation exposure). In addition, about 240,000 recovery operation workers (also called 'liquidators' or 'clean up workers') were called upon in 1986 and 1987 to take part in major mitigation activities at the reactor and within the 30 km zone surrounding the reactor. Residual mitigation activities continued on a relatively large scale until 1990. Altogether, about 600,000 persons (civilian and military) have received special certificates confirming their status as liquidators, according to laws promulgated in Belarus, the Russian Federation, and Ukraine.

In addition, massive releases of radioactive materials into the atmosphere brought about the evacuation of about 116,000 people from areas surrounding the reactor during 1986, and the relocation, after 1986, of about 220,000 people from Belarus, the Russian Federation, and Ukraine.

The accident at the Chernobyl nuclear power plant occurred during a low-power engineering test of the Unit 4 reactor. Improper, unstable operation of the reactor allowed an uncontrollable power surge to occur, resulting in successive steam explosions that severely damaged the reactor building and completely destroyed the reactor.

The radionuclide releases from the damaged reactor occurred mainly over a ten day period, but with varying release rates. From the radiological point of view, ^{131}I and ^{137}Cs are the most important radionuclides to consider, because they are responsible for most of the radiation exposure received by the general population. The releases of ^{131}I and 137Cs are estimated to have been 1,760 and 85 PBq, respectively (1 PBq = 1015 Bq). It is worth noting, however, that the doses were estimated on the basis of environmental and thyroid or body measurements, and that knowledge of the quantities released was not needed for that purpose.

The three main areas of contamination, defined as those with ^{137}Cs deposition density greater than 37 kBq m^{-2} (1 Ci km^{-2}), are in Belarus, the Russian Federation and Ukraine; they have been designated the Central, Gomel-Mogilev-Bryansk and Kaluga-Tula-Orel areas. The Central area is within about 100 km of the reactor, predominantly to the west and northwest. The Gomel-Mogilev-Bryansk contamination area is centered 200 km to the north-northeast of the reactor, at the boundary of the Gomel and Mogilev regions of Belarus and of the Bryansk region of the Russian Federation. The Kaluga-Tula-Orel area is located in the Russian Federation, about 500 km to the northeast of the reactor. Altogether, territories with an area of approximately 150,000 km^2 were contaminated in the former Soviet Union. About five million people reside in those territories.

Outside the former Soviet Union, there were many areas in northern and eastern Europe with ^{137}Cs deposition density in the range of 37-200 kBq m^{-2}. These regions represent an area of 45,000 km^2, or about one third of the contaminated areas found in the former Soviet Union.

The highest doses were received by the approximately six hundred emergency workers who were on the site of the Chernobyl power plant during the night of the accident. The most important exposures were due to external irradiation, as the intake of radionuclides through inhalation was relatively small in most cases. Acute radiation sickness was confirmed for 134 of those emergency workers. Forty-one of these patients received whole-body doses from external irradiation of less than 2.1 Gy. Ninety-three (93) patients received higher doses and had more severe acute radiation sickness: 50 persons with doses between 2.2 and 4.1 Gy, 22 between 4.2 and 6.4 Gy, and 21 between 6.5 and 16 Gy. The skin doses from beta exposures evaluated for eight patients with acute radiation sickness ranged from 10 to 30 times the whole body doses from external irradiation.

The thyroid doses received by the evacuees varied according to their age, place of residence and date of evacuation. For example, the residents of Pripyat, who were evacuated essentially within 48 hours after the accident, the population-weighted average thyroid dose is estimated to be 0.17 Gy, and to range from 0.07 Gy for adults to 2 Gy for infants. For the entire population of evacuees, the population-weighted average thyroid dose is estimated to be 0.47 Gy. Doses to organs and tissues other than the thyroid were, on average, much smaller.

Following the first few weeks after the accident when ^{131}I was the main contributor to the radiation exposures, doses were delivered at much lower dose rates by radionuclides with much longer half-lives. Since 1987, total doses received by the populations of the contaminated areas have resulted essentially from external exposure from ^{134}Cs and ^{137}Cs deposited on the ground, and internal exposure due to contamination of foodstuffs by ^{134}Cs and ^{137}Cs. Other, usually minor, contributions to the long term radiation exposures include the consumption of foodstuffs contaminated with ^{90}Sr and the inhalation of aerosols containing isotopes of plutonium. Both external irradiation and internal irradiation due to ^{134}Cs and ^{137}Cs result in relatively uniform doses in all organs and tissues of the body. The average effective doses from ^{134}Cs and ^{137}Cs that were received during the first ten years after the accident by the residents of contaminated areas are estimated to be about 10 mSv. The median effective dose was about 4 mSv and only about 10,000 people are estimated to have received effective doses greater than 100 mSv. The lifetime effective doses are expected to be about 40% greater than the doses received during the first ten years following the accident.

The Tokaimura, Japan, criticality accident

In 1999 at Tokaimura, Japan, a criticality accident occurred in a fuel conversion plant, involving the processing of highly enriched fuel for an experimental fast reactor. Using unauthorized procedures, the workers poured 16.6 kg of 18.8% enriched uranium into a precipitation tank, resulting in the critical excursion.

Fig. 33. Tokaimura plant

Three workers (A, B and C) received doses ranging from 10 to 20 Gy, from 6 to 10 Gy and from 1.2 to 5.5 Gy, respectively. The workers (A and B) receiving the highest doses later died, the first at 83 days and the second at 211 days after the accident. Of the radiation workers recruited to work under conditions of managed radiation exposure, 21 of them were engaged in the operation to drain water from the cooling jacket; their range of estimated doses (gamma plus neutrons) was 0.04-119 mGy. Six of them were engaged in the operation to feed boric acid into the precipitation tank; the range of estimated doses (gamma plus neutrons) was 0.034-0.61 mGy. For 56 other workers at the site, the range of estimated doses (gamma plus neutrons) was 0.1-23 mGy. For three Tokaimura emergency service workers who took the three exposed workers (A, B and C) to hospital, the range of estimated doses (gamma plus neutrons) was 0.5-3.9 mGy. Seven local workers assembling scaffolding on a construction site had a range of estimated doses (gamma plus neutrons) of 0.4-9.1 mGy.

Although the Tokaimura criticality accident presented some consequences to nearby populations, no significant long term effects are expected. Of the approximately two hundred residents who were evacuated from within 350 m radius, about 90% received doses <5 mSv, and, of the remainder, none received >25 mSv. While there was measurable contamination from deposition of airborne fission products off the site, this contamination did not last long and maximum readings were less than 0.01 mSv h-1.

Several criticality accidents have occurred over the past fifty years. These accidents release a large amount of radiation in a very short space of time. They have often resulted in fatal doses to those in the vicinity; they do not, however, release sufficient radioactive material into the atmosphere or emit sufficient radiation to be a health threat beyond 1 km from the event (in most cases it is within much smaller distances).

The Fukushima accident

The Great East Japan Earthquake occurred on 11 March 2011. The earthquake's epicenter lay off the eastern coastline of Japan generating a tsunami which struck a wide area of coastal Japan, where several waves reached heights of 10-14 metres. The earthquake and tsunami caused more than 15000 life's killed and widespread devastation in Japan.

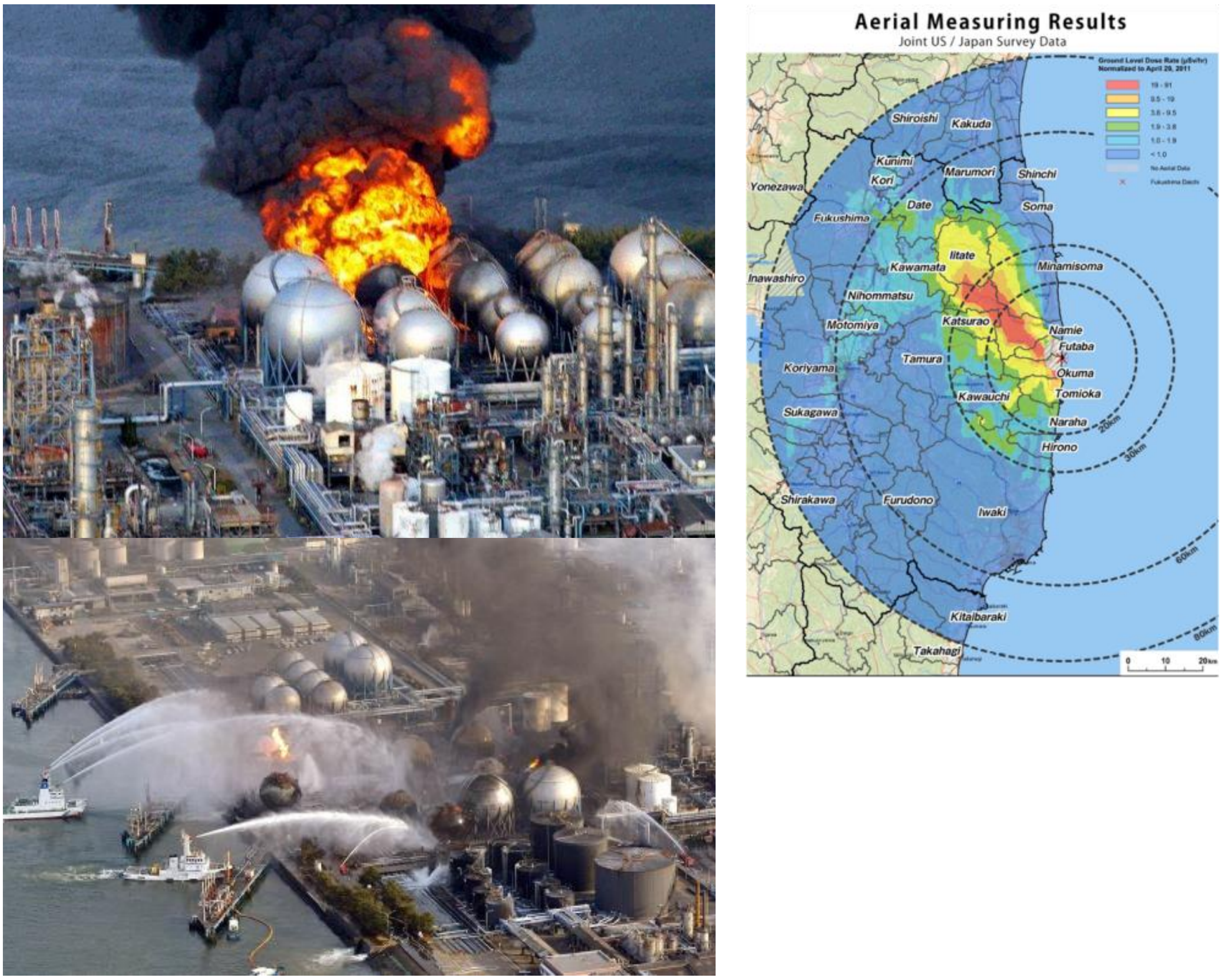

Fig. 34. Fukushima Daiichi Nuclear Power Plant

The tsunami also led to one of the most severe nuclear power site accidents in history, at the Tokyo Electric Power Company (TEPCO) Fukushima Daiichi Nuclear Power Plant. Three of the station's six reactors suffered core melts and the entire facility was severely damaged. The Great East Japan Earthquake, the tsunami, the nuclear accident, and the resulting release of radioactive material led local authorities to initiate an evacuation of approximately 160 000 people.

The earthquake led to the loss of off-site and on-site electrical power which caused the loss of the cooling function at the three operating reactor units as well as at the spent fuel pools. All operating reactor units at these plants were safely shut down but despite the efforts, the reactor cores in two Units overheated, the nuclear fuel melted, and the three containment vessels were breached. Explosions inside the reactor buildings damaged structures and equipment, and injured personnel. The four other NPP along the coast were also affected to different degrees by the earthquake and tsunami.

The initial decisions on protective actions towards the public included: evacuation, sheltering, restrictions on the consumption of food and drinking water, relocation, and the provision of information. Administration of stable iodine for iodine thyroid blocking was not implemented uniformly, primarily due to the lack of detailed arrangements.

The evacuation of people from the vicinity of the Fukushima Daiichi nuclear power plant gradually extended from a radius of 2 km of the plant to 3 km, and by the evening of 12 March, it had been extended to 20 km.

The protection of workers against radiation exposure was severely affected by the extreme conditions at the site, and there were no arrangements in place to integrate into the response the additional emergency personnel who had not been designated prior to the accident. In order to maintain an acceptable level of protection for on-site emergency workers, a range of impromptu measures was implemented.

The total release of radionuclides was estimated at about 20% of the releases from the Chernobyl nuclear power plant Most of the atmospheric releases were blown eastward towards the North Pacific Ocean, and there were also liquid discharges to the sea directly. A relatively small part (about 20%) of the atmospheric releases were deposited on land.

Radionuclides such as iodine-131, caesium-134 and caesium-137 were released and found in drinking water, food and some non-edible items. Restrictions were placed on the distribution and consumption of food and the consumption of drinking water.

For the members of the public at large, the estimates used indicate that the effective doses incurred were low, and no early radiation induced health effects were observed.

For children, the reported thyroid equivalent doses were low because their intake of iodine-131 was limited, partly due to the restrictions placed on drinking water and food. So far, prenatal radiation effects have not been observed, and unwanted terminations of pregnancy attributable to the radiological situation have not been reported. The UNSCEAR organisation found that “no discernible increased incidence of radiation-related health effects are expected among exposed members of the public and their descendants”. The most important health effect is on mental and social wellbeing, related to the enormous impact of the earthquake, tsunami and nuclear accident.

For the around 23 000 emergency workers involved in the emergency operations, the effective doses incurred by most were below the occupational dose limits in Japan. Of this number, 174 exceeded the original criterion for emergency workers, and 6 emergency workers exceeded the temporarily revised effective dose criterion in an emergency situation.

The average effective dose of the evacuated population, depending on the time spent in the weather observation zone, is 6-10 mSv for the first year after the rain. Residents of Fukushima Prefecture received an average dose below 4 mSv, and exposure of most of the population to imaging exposures at or well below background perception exposure. The 25,000 workers who participated in the autumn season from its beginning until October 2012 received an average frequency of 12 mSv. Of this number, 173 doses exceeded 100 mSv, and six TEPCO employees exceeded 250 mSv. The overexposure of six employees was mainly internal respiration of radioactive iodine-131.

Overview of the past radiological emergencies

The Goiania accident

The accident in Goiania was one of the most serious radiological accidents to have occurred to date. It resulted in the death of four persons and the injury by radiation of many others; it also led to the radioactive contamination of parts of the city.

Goiania, a city of one million, is the capital of Goias state in Brazil. In 1985 there was an acrimonious break up of a private medical practice that ran a clinic containing a radiotherapy unit with a very dangerous radioactive source (50.9 TBq caesium-137). When the clinic facility was no longer being used, no one took responsibility for a radiotherapy unit containing the dangerous source. The closing of the facility had been precipitated by the land owner wanting to redevelop the site. During preparation of the site for redevelopment, the clinic was partly demolished but the developer ran out of money. As a result, the radiotherapy unit was left abandoned in an abandoned building.

Two local people hearing rumours that equipment had been left in the abandoned clinic went to the abandoned building. They found a radiotherapy unit, and not knowing what the unit was, but thinking it might have some scrap value, removed the dangerous radioactive source assembly from the head of the unit. This they took home and tried to dismantle, and in the process the source capsule was ruptured. The radioactive material in the capsule was in the form of Caesium chloride salt, which is highly soluble and readily dispersible. After the source capsule was ruptured, the remnants of the source assembly were sold for scrap to a junkyard owner. He noticed that the source material glowed blue in the dark. Several persons were fascinated by this, and over a period of days, friends and relatives came and saw the phenomenon. Fragments of the source the size of rice grains were distributed to several families, resulting in external exposure and ingestion of the Caesium chloride salt. This proceeded for five days, resulting in the contamination of a large area and severe exposure of a number of people who were showing symptoms: namely nausea and vomiting, and later skin lesions.

Within a few days, one of those suffering from symptoms when to a doctor, but the symptoms were not recognized as being due to irradiation and he was sent home. About two weeks later, after many people had fallen ill, one person became convinced that the glowing powder from the source assembly was causing the sickness. She put the remnants of the source assembly in a bag. She took the bag by bus to a local doctor and placed the bag on his desk and told him that it was "killing her family". The doctor became worried and removed the bag to a courtyard where it remained for one day.

At about the same time, one of the doctors treating the victims became suspicious that the skin lesions had been caused by radiation. This resulted in a call to the doctor that had received the bag with parts of the source, who then decided to have the suspicious bag monitored to see if it was radioactive. When a medical physicist went to the office of the doctor with the suspicious bag, he immediately deflected full scale readings on his dose rate monitor, irrespective of the direction in which he pointed it. He assumed the meter was defective and fetched a replacement. When the replacement was switched on, it also showed very high dose rates in all directions, which convinced him that it was a major source of radiation.

The medical physicist and doctor immediately evacuated some of the local people and reported the situation to the local authorities, who in turn reported it to the national authorities in Rio de Janeiro. There were, however, no local or national emergency arrangements to deal with such an accident, and all resources were located in Rio and Sao Paolo both over 1300 km away.

The local authorities evacuated residents from the contaminated areas to a football stadium to await triage by experts, who started to arrive early the next day. It took five days to gain control of the emergency.

A monitoring service for people and objects was carried out at the Olympic Stadium of Goiania. In total, about 110,000 persons reported to the Olympic Stadium for monitoring. Of these, 249 were shown to be contaminated. Those with only external contamination were decontaminated, but 129 people were found to also have internal contamination and were referred for medical care. Seventy-nine persons with low whole body doses, as determined by cytogenetic methods, were managed as outpatients. Fifty persons required close medical surveillance; thirty of them remained under medical observation at the primary care unit, and the other 20 were hospitalized at a secondary care unit. Fourteen of these patients required intensive medical care and were sent to the tertiary care unit in Rio de Janeiro. Four persons died within one month of the event from complications of acute radiation syndrome, including bleeding and infection.

About 150 persons who were exposed and/or contaminated are being followed up; the health effects that have occurred within this group have been reported in. The estimated collective doses were 56.3 person Sv for external exposure and 3.7 person Sv from internal exposure, including 14.9 person Sv (external) and 2.3 person Sv (internal) for the four persons who died.

Initially, contaminated sites were identified based on information provided by the persons being examined. Some places had a high contamination level. In total, 85 residences were found to have significant levels of contamination and 41 were evacuated. Seven houses have been demolished. In addition to residences, 45 public places (including streets, squares and shops) were decontaminated. Contamination was also found on approximately 50 vehicles. The implementation of decontamination programme lasted six months. The total volume of waste removed was 3,500 m3. Lack of initial agreement as to where to locate the temporary waste repository almost brought the programme to a stop. It took the personal intervention of the Brazilian president to overcome the problem. The building of the final repository was accomplished in 1997, almost ten years after the accident. Altogether, 755 professionals were involved in the accident response and subsequent decontamination. In addition, international assistance was supplied through bilateral arrangements and under the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

The San Jose, Costa Rica accident

The start of the event occurred at the San Juan de Dios Hospital in San Jose on 22 August 1996, when a ^{60}Co radiation therapy source was replaced. When the new source was calibrated, an error was made in calculating the dose rate. This miscalculation resulted in the administration to patients of significantly higher radiation doses than those prescribed. This was a major radiation accident; it appears that 115 patients being treated for neoplasms by radiotherapy were affected. The error was recognized on 27 September 1996, and treatments stopped. Officially, the radiotherapy machine was closed down on 3 October 1996.

Measurements on the machine in question, and a review of patient charts confirmed that, the exposure rate had been greater then assumed by about 50-60%. Examination and evaluation were carried out on seventy of the seventy-three patients who remained alive at the time of the IAEA review in July 1997. It was concluded at the time that four patients were suffering from severe consequences and a further 16 patients were experiencing major adverse effects resulting from overexposure and would be at high risk in the future. Twenty-six patients showed effects that were not severe, but could be at some risk of suffering effects in the future. Twenty-two patients had no discernible effects and were considered to be at low risk of future effects, because many had undergone only a small part of their therapy with the replaced source. At least two patients were underexposed. Three patients were not examined.

Forty-two of the patients had died as of 7 July 1997, i.e. within nine months of the accident. Data on thirty-four of these patients were reviewed. It was concluded at that time, when the final answers from full autopsies and a review of the clinical records were still in process of being completed, that three patients may have died as a direct result of overexposure and another four patients were considered to have died with radiation overexposure probably as a major contributory cause of death. Twenty-two patients appeared to have died as a result of their disease rather than radiation exposure, while information on the other five deaths was either inconclusive or unavailable. The findings from examination of the patients and records are summarized in Table below.

FINDINGS OF MEDICAL REVIEW

Number of patients	Adverse effects in surviving patients
4	Severe effects
16	Marked effects, with high risk of future effects
26	Radiation effects that were not severe at the time of examination;some risk of future effects
22	No definite effects of significance at the time of examination; low risk of future effects
2	Underexposed patients as therapy was discontinued (when the error was discovered)
3	Could not be seen; one possibly at risk of future effects
Total 73	

Number of fatalities	Findings in deceased patients
3	Exposure as the major factor in causing death
4	Exposure as a substantial contributory factor
22	Death related to a tumour or cause other than exposure
5	Not enough data to judge
8	Data on patients were not reviewed
Total 42	

The San Salvador accident

An accident occurred in February 1989 at an industrial irradiation facility near San Salvador, El Salvador. Pre-packaged medical products were sterilized at the facility by irradiation of a ^{60}Co source in a movable source rack. The accident happened when this source rack became stuck in the irradiation position. The operator (worker A) bypassed the irradiator's already degraded safety systems and entered the radiation room. On his first entrance, Worker A tried to fix the rack. Unable to free the rack by himself, he left the radiation room about five minutes after his initial entry. Soon afterwards, he returned with two workers (B and C) from another department, who had no experience with the irradiation facility, to help him to free the source rack manually.

The ^{60}Co source elements were contained in doubly encapsulated stainless steel source pencils approximately 45 cm long, with solid stainless steel end caps approximately 1 cm in diameter. Fourteen active source pencils and forty inactive dummy pencils (stainless steel spacer rods) were loaded into each of the two source modules. When the source was installed in June 1975, the total radioactivity of the 60Co gamma source was 4.0 PBq (108 kCi). By the time of the accident its radioactivity had declined to 0.66 PBq (18 kCi).

The next day, the company became aware of the receipt of sick notes for the absent workers A, B and C; however, these notes stated that the men were suffering from food poisoning. The company remained unaware that the accident had caused any radiological injury to the workers until contacted by medical staff from the hospital on day 4. The significance of the injuries was still not appreciated at that time.

For the remainder of the week, the facility was operated more or less normally, with a typical number of shutdowns for repairs, usually requiring entry to the radiation room. It is believed that the source rack was damaged in the first event, which led to a second event later in the week, in the course of which the pencils were all knocked out of the upper source module. One active source pencil was later found to have remained in the radiation room; the others all fell into the water pool.

The elevated radiation level in the radiation room (due to the active source pencil) was detected on day 6. In response to the company's request for help, the supplier sent two of its personnel, who eventually located the active source pencil and moved it into the pool. It was initially believed that this second event had not resulted in the exposure of any personnel. However, cytogenetic tests made in the course of the accident investigation indicated that four workers had received doses in excess of occupational exposure limits.

At the facility, the dose rate monitor was mounted on the wall of the radiation room and interlocked with the personnel access door to prevent access to the radiation room if there were abnormal radiation levels. In order to enter the radiation room, the operator must first press the monitor test button. However, more than five years before the accident, the monitor probe had failed and the probe assembly had been removed, with its cabling remaining in place. Removal of the monitor probe should have disabled the irradiator; but it was discovered that access could be gained to the radiation room by depressing the monitor test switch and repeatedly cycling the buttons on the panel of the radiation monitor. This method of gaining access became the ‘usual’ procedure. Thus, one major safety feature of the design was bypassed.

The practice of using the dose rate monitor outside the closed personnel access door to the radiation room was a crucial factor in the exposure in the second event of at least four workers (the maintenance manager and workers X, Y and Z). The dose rate outside the door would have been at least thirty times lower than the dose rate just inside the entrance maze. Whereas a full (or even half full) source rack in the raised position was detectable with the monitor held outside the closed door, the single active source pencil could only be detected when the monitor was held inside the entrance maze.

None of the workers had worn personal dosimeters. Their exposures were discovered only later, after cytogenetic tests were performed on all workers who might have been exposed as a result of the accident. The estimated doses for these four workers ranged from 0.09 to 0.22 Gy. Had the elevated radiation level in the radiation room due to the active source pencil gone undetected, operating personnel could have accumulated much higher, possibly even lethal, doses through continual uncontrolled exposure.

The three workers (A, B, and C) who were exposed to high radiation doses developed acute radiation syndrome. Their hospital treatments in San Salvador (and subsequently more specialized treatment in Mexico City) were effective in countering the acute effects. However, injuries to the legs and feet of two of the three men were so severe that amputation was required. Worker A, who had received the highest exposure, died six and a half months after the accident, death being attributed to residual lung damage due to irradiation exacerbated by injury sustained during treatment.

For worker B, after amputation, the need for psychological support became the most important factor in his further progress. For Patient C, further rehabilitation therapy was commenced to relieve residual chronic effects, particularly in his more exposed foot

Lessons learned from past emergencies

In regards of Functional Requirements these lessons demonstrate the importance of:

- establishing arrangements for emergency response, in advance and in accordance with the threat category;
- clarifying the roles and responsibilities of those who will be involved in dealing with the response to an emergency, including those involved in directing or managing the response;
- integration of the management of the response of the national authorities with that of the other response organizations as soon as possible, at a single location ideally close to the scene of the emergency;
- all involved in the response recognizing the arrangements that apply to normal situations do not necessarily apply in an emergency.

The most important lessons are listed below.

Identifying, notifying and activating

The importance of:

- the development of operating procedures for facilities within threat categories I, II and III to guide operators in recognizing all accident sequences identified in the safety analysis, including those of low probability;
- those involved in the metal recycling industry being familiar with the trefoil symbol and the devices containing dangerous sources, and the need to monitor the presence of radioactive material incoming as scrap metal and the various product streams;

Taking mitigatory action

The importance of:

- undertaking mitigatory action following the identification of an event situation as rapidly as possible, as delay can exacerbate the consequences;
- arrangements being in place whereby facility operators and those undertaking activities with dangerous mobile sources (threat category IV) can undertake mitigatory action promptly;
- account being taken in emergency arrangements of the actual conditions — for example, areas of high radiation levels — which may affect the functionality of the emergency arrangements and the performance of the emergency procedures;
- account being taken in emergency arrangements of the information and resource requirements of any off-site agencies providing on-site emergency assistance, and of their need to be contacted rapidly and obtain immediate access to the site.

Taking urgent protective action

The importance of:

- prompt action being taken at the time of an emergency to prevent people from receiving high doses, which in turn, avoids the expensive medical treatment (e.g. for radiation-induced injuries or thyroid cancers) that may otherwise be necessary;
- for facilities within threat categories I and II, taking action based on plant conditions, rather than on dose projections derived from atmospheric release data or environmental monitoring;
- establishing, in advance, criteria for action to protect the public for facilities within threat categories I and II and for activities within threat category IV, thereby avoiding ad hoc decisions;
- the emergency plans containing these criteria for urgent protective action to be coordinated with all the authorities involved in responding to the emergency.

The lessons also indicate that:

- concerns about possible panic and traffic risks should not prevent the institution from undertaking evacuation to protect the public;
- administration of stable iodine needs to be done rapidly if it is to be effective in preventing the uptake of radioiodine by the thyroid, but that this may pose difficult logistical problems if the affected population is large;
- the preferred protective action upon the detection of a severe emergency (general emergency), in threat category I or II, is timely evacuation, iodine thyroid blocking and restricting consumption of food and water that may be contaminated, shortly followed by prompt monitoring and further urgent protective actions after a release. These actions will greatly reduce the off-site consequences. However, if evacuation cannot be implemented promptly, sheltering is also a possible countermeasure, but should be used with caution, depending on the nature of the emergency and the construction of buildings. Sheltering, if instituted, can only be a temporary measure;

- the protective action strategy to be implemented in the event of an emergency must be decided in advance after consideration of the site and facility characteristics, and insights on the effectiveness of various protective actions. For threat category I facilities, such as large nuclear reactors, or facilities with large amounts of spent fuel, an effective response strategy for an emergency involving damage to the core or fuel in the spent fuel pool would include:
    - taking precautionary protective action nearby (3-5 km), immediately upon detection of conditions within the facility that are likely leading to core or spent fuel damage, without waiting for dose projections (too slow and uncertain);
    - promptly (within hours) conducting monitoring and initiate appropriate urgent protective action (e.g. evacuation) for the area within about 30 km17 of a large reactor;
    - promptly stopping consumption of local produce, milk from animals grazing on contaminated pasture or rainwater up to a distance of 300 km until sampled and analysed;
    - within days, conducting monitoring of ground deposition and initiate early protective actions (e.g. relocation) for the area within about 250-300 km;
- provision for promptly (within an hour of the predefined criteria being exceeded) making decisions concerning precautionary and urgent protective actions and subsequently notifying the public, is essential to reducing the probability of radiation health effects among the public in the event of a severe emergency;
- although the focus during an emergency will be on the actions to be taken to mitigate the consequences, criteria are also necessary for determining when protective actions can be lifted. People who have been evacuated will naturally wish to return to their homes and re-establish their normal activities. Thus, if precautionary countermeasures have been used, action will be necessary to assess the affected areas against the pre-established criteria so that they can be progressively lifted.

Providing information and issuing instructions and warnings to the public

The importance of:
- including consideration of the provision of public information and warnings in the emergency response plans for facilities in threat categories I and II;
- providing information on the protective actions to be taken in the event of an emergency to be made available to the public in potentially affected areas in advance of any emergency in the case of facilities in threat categories I and II. This will engender confidence — the knowledge that the officials have their interest at heart — and, by doing so, improve compliance with protective action recommendations in the event of a real emergency. In addition, there will be a better understanding of the systems used to warn them of an emergency;
- a coordinated approach to the provision of information to the media, and this should be addressed in the emergency plans.

The lessons also indicate that:
- consideration needs to be given to the demand from the public for information of events in facilities in threat category III, if only to ensure that correct information is given and unnecessary fears are allayed;
- prior thought needs to be given to the means to be used to provide information to the public in the event of an emergency involving an activity within threat category IV;
- the quality of the information disseminated to those at risk substantially determines their ability to protect themselves. Implementation of a protective action by the public after hearing a warning signal (e.g. a siren) is significantly higher when followed by a warning message (e.g. over a loudspeaker or radio) describing the threat, which areas are at risk

(thus requiring protective action) and which areas are not at risk (thus requiring no protective action). The messages should identify the location of the event, the nature of the radiological hazard, and the severity and immediacy of the threat. It is critically important that the message describes the areas at risk in terms of political and geographical boundaries that will be readily recognized by local residents, gives specific recommendations for the actions that they should take to protect themselves, and identifies the legitimate authority making the recommendation. It is also important that the messages are clear, consistent and repeated;
- those transiting through the areas affected by an emergency cannot be expected to understand the warning signals and to know the local landmarks, so specific mechanisms will be needed to contact them and provide them with guidance;
- the media (e.g. local radio stations) can be used effectively as the primary warning method for emergencies at unforeseen locations — threat category IV — and as a supplement to other warning systems.

Protecting emergency workers
The importance of:
- emergency workers being clearly and comprehensively informed in advance of the risks, and to the extent possible, to be trained in the actions that may be required;
- emergency workers being provided with suitable protective and monitoring equipment, and for this equipment to be readily accessible and in sufficient quantity for the postulated emergency;
- the emergency plan reflecting the needs of emergency workers;
- the doses to emergency workers being appropriately assessed and recorded for the purpose of subsequent medical care.

The lessons also indicate that a release of radioactive material can lead to both internal and external radiation exposure. Therefore, direct reading individual dosimeters, which, very often, only measure exposure from external penetrating radiation may not provide a sufficient measure of the hazard and hence, additional criteria may be necessary to manage the exposure of emergency workers.

Assessing the initial phase
The importance of:
- assessing the magnitude and scope of a problem is an evolving process, so emergency responders should continue to assess the problem to test the validity of the initial assessment and monitor changing conditions.

Managing the medical response
The importance of:
- medical professionals being trained to recognize radiation-induced injuries and to understand the difficulties in treatment;
- the physicians involved in treating patients who have received exposures that may result in tissue damage, or life-threatening doses, to promptly consult with other physicians with experience in dealing with severe radiation exposures, and transferring the patient to an appropriate hospital if warranted;
- those involved in emergency response gathering sufficient information to allow the dose profile of the highly exposed individuals to be reconstructed, in order to determine the evolution of the damage and the treatment that is necessary. This information includes:
  a) estimates of the dose received to the whole body or tissues,
  b) photograph/diagrams of the facility/practice involved,

c) a description of the source of exposure (e.g. activity, radionuclide, dose rate at 1 m),
d) a detailed description of circumstances of the exposure (e.g. location of person as a function of time,
e) readings of all individual dosimeters (all staff members) or other monitoring devices,
f) samples of items worn by the overexposed person,
g) a full description and time of onset of any early clinical symptoms,
h) results of a general medical examination of all systems and organs to include the skin for visible muscosa,
i) total blood counts in order to detect the first wave of symptoms related to exposure;

- the authorities establishing plans and procedures: for triage of the victims and transporting them to the appropriate medical facilities, for ensuring that there will be a sufficient number of medical staff available to deal with the postulated number of victims, for collecting individual dosimetry data and providing those data to physicians, for obtaining expert assistance in the diagnosis and treatment of radiation injuries, and for transferring patients who suffered a severe exposure to facilities with experience in treating radiation injuries;
- the national emergency plan having provisions for promptly requesting emergency assistance for dealing with victims from international organizations under the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency;
- establishing criteria for determining the groups which have been highly exposed and should be subject to long term medical follow-up to detect the early appearance of cancer.

The lessons also indicate that the psychological impact of the treatment of radiation- induced injuries must be minimized and therefore the treatment should be provided as close to the individual's home as possible, or in a region with the same language and culture. Provision should be made for family members to accompany the patient when treated in another country.

Keeping the public informed

The major objectives of emergency public information are:

- to ensure that those who are not at risk understand that their safety is being actively monitored and that, unless otherwise instructed, there is no need to take protective actions. This contrasts with the goal of the emergency warning, which is to ensure that all of those at risk comply in a timely manner with authorities' protective action recommendations;
- to ensure that the demand for public information does not detract from the management of the response to the emergency.

These lessons demonstrate the importance of:

- giving careful attention to the provision of timely and accurate public information, both immediately and on an on-going basis, irrespective of whether or not public concern seems misplaced;
- defining the arrangements for providing appropriate information to the public and media in the emergency plan for all facilities in threat categories I, II and III and for activities within threat category IV;
- coordinating the provision of information between the public authorities and operators;
- the staff manning the information centres being trained in providing information to the public and media in a clear and straightforward fashion.

Taking agricultural countermeasures, countermeasures against ingestion and longer term protective actions

The importance of:

- developing OILs for various protective actions in advance and incorporating them into the emergency arrangements;
- using internationally harmonized generic OILs and protective actions;
- providing clear explanations to the public in the case of when and why values need to be changed during an emergency;
- establishing beforehand methods and criteria for decontamination of areas (streets, roofs, surface soil, subsoil, etc.) to reduce dose rates;
- refraining from declaring decontamination operations as completed until a final assessment confirms that dose reduction goals have been achieved.

Mitigating the non-radiological consequences of the emergency and the response

The importance of:

- considering and taking account of the psychological impact that actions undertaken during and subsequent to a serious emergency might have on members of the public;
- basing any system of compensation on pre-established criteria that are clearly linked to health risks and tangible economic impacts.

Conducting recovery operations

The importance of:

- anticipating the intense pressure from the media and the public to return to normal living conditions, which can result in the temptation to engage in actions that have no meaningful impact on public safety;
- the authorities maintaining a high level of credibility in order to facilitate the process of recovery

Best practices used to mitigate the consequence during the event

It is now widely recognized that the achievement and maintenance of a high level of safety depends on there being a sound legal and governmental infrastructure, including a national regulatory body with well-defined responsibilities and functions. Many emergencies would have been more appropriately mitigated if there had been an adequate infrastructure to deal with such emergencies. The emergency functions cannot be expected to be performed appropriately unless an adequate infrastructure for emergency preparedness and response is in place.

These lessons of radiation accidents demonstrate the importance of:

- establishing emergency arrangements, based on a safety analysis, for threat category III, as well as the threat categories I and II, a particular concern being industrial irradiators, which exist in many States throughout the world;
- establishing emergency arrangements for emergencies involving dangerous orphan sources that could occur virtually anywhere; proving the need to identify locations where such sources may be discovered, such as metal recycling industries.

It is difficult to give examples of best practice in mitigating the consequences of a radiation accident, as the analysis of each accident reveals errors in the organization of measures to identify, the extent and persons involved, and in many cases criticize the measures to eliminate the consequences. It is good practice to prepare well for possible emergencies by reviewing the list of possible emergencies and developing measures to eliminate them.

Good practice for the operation of a radioactive facility includes:

- design, modeling and construction of a radioactive facility in compliance with all applicable radiation safety standards, including the calculation of stationary protection (walls, ceilings) depending on the type of radioactive source and its activity;
- use of protective equipment for individual operations and movements of a radioactive source;
- organization of the work process with writing instructions for the performance of work operations in compliance with radiation protection measures;
- educating the personnel of a radioactive facility of a safety culture with strict compliance with the rules of radiation safety when working with any source of ionizing radiation;
- preparation of an emergency plan for each radiation facility. Depending on the hazard category of a radioactive object, the plan can be purely object-oriented, as, for example, in medical institutions with a limited number of radioactive sources for diagnostic or therapeutic purposes, or multi-level: object, local, regional, federal.

The radiation hazard elimination plan, in general, should include:

- planned actions in all areas of activity that were considered earlier;
- hardware and financial support of the planned actions; training of personnel, each of which understands in advance, knows and is able to perform the assigned tasks;
- organizational system of interaction of all branches of power with regional, municipal and facility administrations.

The importance of having clear emergency plans and procedures has already been. The lack of such pre-established plans and procedures has hampered the response to many emergencies.

Problems also arise when emergency plans are developed without the input of those who will actually implement them. The involvement of all the relevant organizations in the development of emergency plans enables the identification of errors in assumptions about response capabilities, increases the understanding of the capabilities of the other response organizations, increases the understanding of what is expected from them and determines the resources needed. It also tends to increase ownership and therefore commitment to successful implementation of the plan.

Well-defined procedures enhance the performance of the difficult tasks that need to be undertaken during an emergency. However, many procedures have been found to be ineffective under emergency conditions because they are poorly designed, needed more time or information than was available, the users did not have the necessary expertise or training, or they were not compatible with other elements of the response system. The effectiveness of procedures can be assessed through testing under realistic emergency conditions during drills and exercises.

Responses to the Chernobyl and Goiania emergencies demonstrated that decisions concerning the implementation of protective actions affecting the public can be made by public officials who are not radiation specialists, and therefore make their decisions on the basis of their own understanding of both the radiological risk and the societal and political concerns.

The failure to make arrangements to deal with the low probability/high consequence events is obvious from the Chernobyl accident. For example, the failure to promptly restrict consumption of locally produced milk and vegetables when there was a severe core damage accident resulted in radiation-induced thyroid cancers. In addition, many fire fighters and other personnel who responded on site died because of high level exposure. They could not measure the dose rates (which could be fatal in minutes) and were not trained or equipped to operate in the severe conditions caused by the accident.

The accident in Goiania and one of a similar scale, also involving a radiotherapy source, in Juarez, Mexico provide examples of low probability radiological events that have resulted in high consequences in the public domain. These emergencies occur in unpredictable locations and have unpredictable consequences. Similarly, the location and consequences of an event involving the use of a radiological dispersal device by terrorists cannot be predicted.

For many years, the UK has had an integrated all hazards emergency response framework. The lessons from Three Mile Island were an input to its development, as equally were experiences from floods, chemical fires, etc. The threat of possible terrorist attacks using CBRN agents has reinforced the need for an all hazards integrated approach. Whatever the emergency affecting the public sector, the police take the lead role. If it is a serious emergency, they will establish a Strategic Coordinating Group (SCG), which they chair. The SCG will have senior representatives from the emergency services, the National Health Service, local authorities, utilities and scientific/ regulatory bodies. Whilst these organizations provide advice, and have their own defined responsibilities, the police are in command of the response. If the emergency is of national importance, such as a large area flooding or multiple sited terrorist attacks, then the police remain in command locally, but national coordination and policy issues would be dealt with by the government through a group known as the Civil Contingencies Committee (CCC) located in dedicated crisis management facilities, the Cabinet Office Briefing Room (COBR). For each type of emergency, there is a designated lead government department, who would chair the CCC, unless the Prime Minister chooses to do so.

This framework has been used to deal with a variety of emergencies: it is also regularly exercised for nuclear sites and possible terrorist attacks. So on 7 July 2005, when four terrorist bombs were detonated in the London transport system, the various responding organizations were clear about their respective roles and responsibilities, and there was a clear command and control structure through the police. These arrangements were also used during the polonium-210 incident in London in 2006 and worked well. Both incidents involved many responding agencies, each of whom had representatives, or were represented by their parent government department, at SCG and CCC. Experience from a variety of previous emergencies has shown the need to also have some key crosslinks with advisers from one agency, embedded within the response structure of another which close working was necessary. This does place demands on senior staff resources, but has to be factored into organizational plans and relevant training programmes.

There have also been serious radiological emergencies involving overexposures caused by operators (e.g. radiographers) of portable dangerous sources trying to recover from, or mitigate, abnormal conditions. These overexposures occurred because of inadequate procedures, training and tools, and a lack of understanding of the basic principles of radiation safety and the operating principles of the devices they were using.

These lessons demonstrate the importance of:

- pre-established plans for emergency response, which need to be written down, shared with all those concerned, cover the full spectrum of possible emergencies including low probability/high consequence events, integrated into an all-hazards emergency management programme and supplemented by written procedures;
- particular consideration being given to the integration of emergency response plans with the arrangements to respond to terrorist and other criminal threats involving radioactive material;
- the development of generic plans and procedures that can provide a command and control infrastructure, and the ability to deploy expertise and resources for emergencies involving activities in threat category.

Conclusion

The analysis of nuclear and radiological accidents and measures to eliminate their consequences shows the need to develop and improve the work on the application of the concept of deep protection and emergency preparedness and response systems as an essential element of this concept.

The lessons demonstrate the importance of undertaking mitigatory action following the identification of an event situation as rapidly as possible, as delay can exacerbate the consequences.

Account being taken in emergency arrangements of the actual conditions — for example, areas of high radiation levels — which may affect the functionality of the emergency arrangements and the performance of the emergency procedures.

Such a process should be flexible to adapt to a variety of situations.

Smaller radiological incidents may be well addressed by existing emergency response and environmental cleanup programs at local, state, tribal and federal levels.

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APPENDIX A

GLOSSARY

Accident. Any unintended event, including operating errors, equipment failures or other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

Acute health effects: health problems caused by high radiation doses received in a short period of time. Examples of acute effects include erythema (reddening of skin), blistering, epilation (hair loss), and vomiting.

Alara: acronym for "as low as reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the activity is undertaken.

Alpha radiation: alpha radiation comes from the ejection of alpha particles from the nuclei of some unstable atoms. An alpha particle is identical to a helium nucleus and consists of two protons and two neutrons. Alpha particles are highly energetic, but can only travel a few centimeters in air. They have low penetrating power and can be stopped by a sheet of paper. Alpha particles generally cannot even penetrate the layer of dead cells on the skin, but can pose a health risk when inhaled or ingested.

Arrangements (for emergency response). The integrated set of infrastructural elements necessary to provide the capability for performing a specified function or task required in response to a nuclear or radiological emergency. These elements may include authorities and responsibilities, organization, coordination, personnel, plans, procedures, facilities, equipment or training.

Avertable dose. The dose that could be averted if a countermeasure or set of countermeasures were to be applied.

Avoided dose: the radiation dose saved by implementing a protective action.

Best available technologies (bat): bats are treatment technologies, treatment techniques, or other means that the u.s. epa administrator determines to be available, after examination for efficacy under field conditions and not solely under laboratory conditions (taking cost into consideration).

Beta radiation: beta radiation comes from the emission of beta particles during radioactive decay. Beta particles are highly energetic and fast-moving. They carry a positive or negative charge and can be stopped by a layer of clothing or few millimeters of a solid material. Beta particles can penetrate the skin and cause skin burns, but tissue damage is limited by their small size. Beta particles are most hazardous when inhaled or ingested.

Centigray (cgy): one cgy is equal to one hundredth of a gray (0.01gy). See gray. One cgy is equivalent to one rad. See rad.

Chronic effects: health problems caused by radiation doses delivered over a long period. Examples of chronic effects include cancer and genetic mutations.

Cloudshine: gamma radiation emitted from an airborne plume overhead.

Collective dose. The total radiation dose incurred by a population.

Committed effective dose: the sum of the committed equivalent doses following intake (inhalation or ingestion) of a radionuclide to each organ multiplied by a tissue weighting factor.

Community water systems (cws): a public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

Concentration: radionuclide activity per unit of mass.

Contamination: radionuclides on a surface or in the environment as a result of an accidental release.

Dangerous source. A source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects. This categorization is used for determining the need for emergency response arrangements and is not to be confused with categorizations of sources for other purposes.

Derived intervention level (dil): concentration derived from the intervention level of dose at which introduction of protective measures should be considered. (fda 1998)

Derived response level (drl): a level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding protective action guide.

Deterministic effect. A health effect of radiation for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a 'severe deterministic effect' if it is fatal or life threatening or results in a permanent injury that reduces quality of life.

Dose: the amount of radiation exposure a person has received, calculated considering the effectiveness of the radiation type (alpha, beta, gamma), the timeframe of the exposure, and the sensitivity of the person or individual organs.

Dose parameter (dp): any factor that is used to change an environmental measurement to dose in the units of concern.

Dose projection: a calculated future dose that an individual might receive; also the process of making these calculations.

Dose reduction factor: a factor by which a decontamination technique or protective action reduces the radiation dose to a person.

Dosimetry: the system for assessing radiation doses from external radiation exposures and from intakes of radionuclides using biokinetic models and dosimetric quantities developed by the icrp and the international commission on radiation units and measurements (icru).

Early phase: the beginning of a radiological incident for which immediate decisions for effective use of protective actions are required and must therefore be based primarily on the status of the radiological incident and the prognosis for worsening conditions. This phase may last from hours to days.

Effective dose: the sum of organ equivalent doses weighted by icrp organ weighting factors.

Emergency action level (eal). A specific, predetermined, observable criterion used to detect, recognize and determine the emergency class.

Emergency class. A set of conditions that warrant a similar immediate emergency response. This is the term used for communicating to the response organizations and the public the level of response needed. The events that belong to a given emergency class are defined by criteria specific to the installation, source or practice, which if exceeded indicate classification at the prescribed level. For each emergency class, the initial actions of the response organizations are predefined.

Emergency classification. The process whereby an authorized official classifies an emergency in order to declare the applicable emergency class. Upon declaration of the emergency class the response organizations initiate the predefined response actions for that emergency class.

Emergency phase. The period of time from the detection of conditions warranting an emergency response until the completion of all the actions taken in anticipation of or in response to the radiological conditions expected in the first few months of the emergency. This phase typically ends when the situation is under control, the off-site radiological conditions have been characterized sufficiently well to identify where food restrictions and temporary relocation are required, and all required food restrictions and temporary relocations have been implemented.

Emergency plan. A description of the objectives, policy and concept of operations for the response to an emergency and of the structure, authorities and responsibilities for a systematic, coordinated and effective response. The emergency plan serves as the basis for the development of other plans, procedures and checklists.

Emergency planning zone: a designated zone around a commercial nuclear power plant for which radiological response plans must be maintained under nuclear regulatory commission regulations.

Emergency preparedness. The capability to take actions that will effectively mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment.

Emergency procedures. A set of instructions describing in detail the actions to be taken by response personnel in an emergency.

Emergency response. The performance of actions to mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment. It may also provide a basis for the resumption of normal social and economic activity.

Emergency services. The local off-site response organizations that are generally available and that perform emergency response functions. These may include police, firefighters and rescue brigades, ambulance services and control teams for hazardous materials.

Emergency worker: anyone with a role in responding to the incident whether a radiation worker previously or not, who should be protected from radiation exposure in excess of occupational dose limits while performing actions to mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment.

Emergency zones. The precautionary action zone and/or the urgent protective action planning zone.

Emergency. A non-routine situation or event that necessitates prompt action, primarily to mitigate a hazard or adverse consequences for human health and safety, quality of life, property or the environment. This includes nuclear and radiological emergencies and conventional emergencies such as fires, release of hazardous chemicals, storms or earthquakes. It includes situations for which prompt action is warranted to mitigate the effects of a perceived hazard.

Evacuation: the urgent removal of people from an area to avoid or reduce high-level, short-term exposure, from the plume or from deposited radioactivity. Evacuation may be a preemptive action taken in response to a facility condition rather than an actual release.

Exposure. The act or condition of being subject to irradiation. Exposure can be either external exposure (due to a source outside the body) or internal exposure (due to a source within the body).

First responders. The first members of an emergency service to respond at the scene of an emergency.

Gamma radiation: gamma radiation comes from the emission of high-energy, weightless, chargeless photons during radioactive decay. Gamma photons are pure electromagnetic energy and highly penetrating—several inches of lead or a few feet of concrete may be required to attenuate them. External exposure to gamma rays poses a health threat to the entire body. Inhalation and ingestion of gamma emitters also poses a health threat.

Graves' disease: an autoimmune disorder that leads to the over activity of the thyroid.

Gray (gy): international unit of absorbed radiation dose. One gy is equivalent to 100 rad. See rad.

Groundshine: gamma radiation emitted from radioactive materials deposited on the ground.

Half-life: the time required for half the atoms of a given radioisotope to transform by radioactive decay.

Hashimoto's thyroiditis: an autoimmune disorder that leads to underactive thyroid with bouts of over activity.

Improvised nuclear device (ind): a crude, yield-producing nuclear weapon fabricated from diverted fissile material.

Incident. Any unintended event, including operation errors, equipment failures, initiating events, accident precursors, near misses or other mishaps, or unauthorized act, malicious or non-malicious, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

Initial phase. The period of time from the detection of conditions that warrant the performance of response actions that must be taken promptly in order to be effective until those actions have been completed. These actions include mitigatory actions by the operator and urgent protective actions on and off the site.

Intermediate phase: the period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these additional protective actions are no longer needed. This phase may overlap the early phase and late phase and may last from weeks to months.

Intervention level. The level of avertable dose at which a specific protective action is taken in an emergency or a situation of chronic exposure.

Intervention. Any action intended to reduce or avert exposure or the likelihood of exposure to sources that are not part of a controlled practice or that are out of control as a consequence of an accident.

Isodose-rate line: a contour line that is used to connect points of equal radiation dose rates.

Late phase: the period beginning when recovery actions designed to reduce radiation levels in the environment to acceptable levels are commenced and ending when all recovery actions have been completed. This phase may extend from months to years. A pag level, or dose to avoid, is not appropriate for long-term cleanup.

Latency period, cancer: the time elapsed between radiation exposure and the onset of cancer.

Longer term protective action. A protective action that is not an urgent protective action. Such protective actions are likely to be prolonged over weeks, months or years. These include measures such as relocation, agricultural countermeasures and remedial actions.

Maximum contaminant level (mcl): an enforceable standard established to protect the public against consumption of drinking water contaminants that present a risk to human health. A mcl is the maximum allowable amount of a contaminant in drinking water that is delivered to the consumer.

Microsievert (μsv): one millionth of a sievert. See sievert. One ten-thousandth of a rem. See rem. (1 μsv = 0.1 mrem (millirem))

Millirem (mrem): one thousandth of a rem. See rem. (1 mrem = 0.00001 sv (sievert) = 0.01 msv (millisievert) = 10 μsv (microsievert))

Millisievert (msv): one thousandth of a sievert. See sievert. (1 msv = 100 mrem (millirem) = 0.1 rem)

Mitigatory action. Immediate action by the operator or other party:

(1) To reduce the potential for conditions to develop that would result in exposure or a release of radioactive material requiring emergency actions on or off the site; or

(2) To mitigate source conditions that may result in exposure or a release of radioactive material requiring emergency actions on or off the site.

Noble gases: a group of elemental gases that are tasteless, odorless, and that do not undergo chemical reactions under natural conditions. The noble gases consist of helium (he), neon (ne), argon (ar), krypton (kr), xenon (xe), and radon (rn).

Notification:

(1) A document submitted to the regulatory body by a legal person to notify an intention to carry out a practice or other use of a source;

(2) A report submitted promptly to a national or international authority providing details of an emergency or a possible emergency, for example as required by the convention on early notification of a nuclear accident;

(3) A set of actions taken upon detection of emergency conditions with the purpose of alerting all organizations with responsibility for emergency response in the event of such conditions.

Notification point. A designated organization with which arrangements have been made to receive notification (meaning (3)) and to initiate promptly the predetermined actions to activate a part of the emergency response.

Notifying state. The state that is responsible for notifying (meaning (1)) potentially affected states and the iaea of an event or situation of actual, potential or perceived radiological significance for other states. This includes:

— The state party that has jurisdiction or control over the facility or activity (including space objects) in accordance with article 1 of the convention on early notification of a nuclear accident; or

— The state that initially detects, or discovers evidence of, a transnational emergency, for example by detecting significant increases in atmospheric radiation levels of unknown origin; detecting contamination in transboundary shipments; discovering a dangerous source that may have originated in another state; or diagnosing medical symptoms that may have resulted from exposure outside the state.

Nuclear or radiological emergency. An emergency in which there is, or is perceived to be, a hazard due to:

(a) The energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction; or

(b) Radiation exposure.

Off-site: areas outside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may also be used to refer to areas impacted by contamination.

Off-site. Outside the site area.

On-site: areas inside the controlled border of a facility, such as a nuclear power plant. For an incident not involving a facility, this term may refer to areas controlled during a response.

On-site. Within the site area.

Operational intervention level (oil). A calculated level, measured by instruments or determined by laboratory analysis, that corresponds to an intervention level or action level. Oils are typically expressed in terms of dose rates or of activity of radioactive material released, time integrated air concentrations, ground or surface concentrations, or activity concentrations of radionuclides in environmental, food or water samples. An oil is a type of action level that is used immediately and directly (without further assessment) to determine the appropriate protective actions on the basis of an environmental measurement.

Operator (or operating organization). Any organization or person applying for authorization or authorized and/or responsible for nuclear, radiation, radioactive waste or transport safety when undertaking activities or in relation to any nuclear facilities or sources of ionizing radiation. This includes private individuals, governmental bodies, consignors or carriers, licensees, hospitals, self-employed persons, etc. Operator includes either those who are directly in control of a facility or an activity during use of a source (such as radiographers or carriers) or, in the case of a source not under control (such as a lost or illicitly removed source or a re-entering satellite), those who were responsible for the source before control over it was lost.

Potassium iodide: a salt of stable, non-radioactive iodine in medicine form. The administration of potassium iodide saturates the thyroid with non-radioactive iodine, so it does not absorb radioactive iodine released into the environment from a radiological incident.

Practice. Any human activity that introduces additional sources of exposure or exposure pathways or extends exposure to additional people or modifies the network of exposure pathways from existing sources, so as to increase the exposure or the likelihood of exposure of people or the number of people exposed.

Precautionary action zone. An area around a facility for which arrangements have been made to take urgent protective actions in the event of a nuclear or radiological emergency to reduce the risk of severe deterministic effects off the site. Protective actions within this area are to be taken before or shortly after a release of radioactive material or an exposure on the basis of the prevailing conditions at the facility.

Projected dose: the prediction of the dose that a population or individual could receive.

Prophylactic: a treatment or medication designed to prevent exposure to radiation.

Protective action guide (pag): the projected dose to an individual, resulting from a radiological incident at which a specific protective action to reduce or avoid that dose is warranted.

Protective actions: an activity conducted in response to an incident or potential incident to avoid or reduce radiation dose to members of the public in emergencies or situations of chronic exposure.

Rad (radiation absorbed dose)**:** a basic unit of absorbed radiation dose. It is being replaced by the “gray,” which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy, per gram of material.

Radiation protection officer. A person technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant or licensee to oversee the application of relevant requirements established in international safety standards.

Radiation specialist. A person trained in radiation protection and other areas of specialization necessary in order to be able to assess radiological conditions, to mitigate radiological consequences or to control doses to responders.

Radioactive: quality of a material that emits alpha particles, beta particles, gamma rays, or neutrons.

Radiological assessor. A person who in the event of a nuclear or radiological emergency assists the operator of a dangerous source by performing radiation surveys, performing dose assessments, controlling contamination, ensuring the radiation protection of emergency workers and formulating recommendations on protective actions. The radiological assessor would generally be the radiation protection officer.

Radiological dispersal device (rdd): a device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means. An rdd is commonly known as a “dirty bomb.”

Radiopharmaceutical: a radioactive chemical used for diagnosis, cure, treatment, or prevention of diseases.

Recovery: the phase after response when efforts focus on remediation, or the process of reducing radiation exposure rates and concentrations of radioactive material in the environment to levels acceptable for unconditional occupancy or use.

Reentry: workers or members of the public going into relocation or radiological contaminated areas on a temporary basis under controlled conditions.

Regulatory body. An authority or a system of authorities designated by the government of a state as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating nuclear, radiation, radioactive waste and transport safety.

Release: uncontrolled distribution of radioactive material to the environment.

Release rate: the measure of the amount of radioactive material dispersed per unit of time.

Relocation: the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. Not to be confused with *evacuation*.

Rem (roentgen equivalent man): the product of the absorbed dose in rads and a weighting factor which accounts for the effectiveness of the radiation to cause biological damage; a conventional unit for equivalent dose. One rem equals 0.01 sv.

Reoccupancy: the return of households and communities to relocation areas during the cleanup process, at radiation levels acceptable to the community.

Response organization. An organization designated or otherwise recognized by a state as being responsible for managing or implementing any aspect of an emergency response.

Return: permanent resettlement in evacuation or relocation areas with no restrictions, based on acceptable environmental and public health conditions.

Roentgen (r): a conventional unit for exposure. For x-ray and gamma radiation, rad ~ rem ~ roentgen (r). A handheld survey meter that reads in r/hr can be used to measure exposure rates.

Shelter-in-place: the action of staying or going indoors immediately.

Sievert (sv): international unit of equivalent dose. One sievert equals 100 rem. (1 sv = 1,000 msv (millisieverts) = 1,000,000 μsv (microsieverts) = 100 rem = 100,000 mrem (millirem))

Significant transboundary release. A release of radioactive material to the environment that may result in doses or levels of contamination beyond national borders from the release which exceed international intervention levels or action levels for protective actions, including food restrictions and restrictions on commerce.

Site area. A geographical area that contains an authorized facility, activity or source, and within which the management of the authorized facility or activity may directly initiate emergency actions. This is typically the area within the security perimeter fence or other designated property marker. It may also be the controlled area around a radiography source or a cordoned off area established by first responders around a suspected hazard.

Small system compliance technologies (ssct): treatment technologies that achieve compliance with maximum contaminant levels and which have been identified by epa as being affordable for small drinking water systems serving fewer than 10,000 persons.

Source term: the amount of a contaminant available in a scenario or actually released to the environment.

Source. Anything that may cause radiation exposure — such as by emitting ionizing radiation or by releasing radioactive substances or materials — and can be treated as a single entity for protection and safety purposes. For example, materials emitting radon are sources in the environment; a sterilization gamma irradiation unit is a source for the practice of radiation preservation of food; an x ray unit may be a source for the practice of radiodiagnosis; a nuclear power plant is part of the practice of generating electricity by nuclear fission, and may be regarded as a source (e.g. With respect to discharges to the environment) or as a collection of sources (e.g. For occupational radiation protection purposes). A complex or multiple installation situated at one location or site may, as appropriate, be considered a single source for the purposes of application of international safety standards.

Special facility. A facility for which predetermined facility specific actions need to be taken if urgent protective actions are ordered in its locality in the event of a nuclear or radiological emergency. Examples include chemical plants that cannot be evacuated until certain actions have been taken to prevent fire or explosions and telecommunications centres that must be staffed in order to maintain telephone services.

Special population groups. Members of the public for whom special arrangements are necessary in order for effective protective actions to be taken in the event of a nuclear or radiological emergency. Examples include disabled persons, hospital patients and prisoners.

Stay time: term of art used in the radiation safety field. Stay times are the amount of time a person may access the contaminated area. These times vary based upon site-specific factors or incident characteristics such as indoor or outdoor work, sensitive populations, and level of radioactivity.

Stochastic effect (of radiation). A radiation induced health effect, the probability of occurrence of which is greater for a higher radiation dose and the severity of which (if it occurs) is independent of dose. Stochastic effects may be somatic effects or hereditary effects, and generally occur without a threshold level of dose. Examples include various forms of cancer and leukaemia.

Total effective dose (ted): the sum of the effective dose (for external exposures) and the committed effective dose; also referred to in this manual as whole body dose. See section 2.3.

Threat assessment. The process of analysing systematically the hazards associated with facilities, activities or sources within or beyond the borders of a state in order to identify:

(a) Those events and the associated areas for which protective actions may be required within the state;

(b) The actions that would be effective in mitigating the consequences of such events.

Transnational emergency. A nuclear or radiological emergency of actual, potential or perceived radiological significance for more than one state. This includes:

(1) A significant transboundary release of radioactive material (however, a transnational emergency does not necessarily imply a significant transboundary release of radioactive material);

(2) A general emergency at a facility or other event that could result in a significant transboundary release (atmospheric or aquatic) of radioactive material;

(3) Discovery of the loss or illicit removal of a dangerous source that has been transported across or is suspected of having been transported across a national border;

(4) An emergency resulting in significant disruption to international trade or travel;

(5) An emergency warranting the taking of protective actions for foreign nationals or embassies in the state in which it occurs;

(6) An emergency resulting in or potentially resulting in severe deterministic effects and involving a fault and/or problem (such as in equipment or software) that could have implications for safety internationally;

(7) An emergency resulting in or potentially resulting in great concern among the population of more than one state owing to the actual or perceived radiological hazard.

Urgent protective action planning zone. An area around a facility for which arrangements have been made to take urgent protective actions in the event of a nuclear or radiological emergency to avert doses off the site in accordance with international safety standards. Protective actions within this area are to be taken on the basis of environmental monitoring or, as appropriate, prevailing conditions at the facility.

Urgent protective action. A protective action in the event of an emergency which must be taken promptly (normally within hours) in order to be effective, and the effectiveness of which will be markedly reduced if it is delayed. The most commonly considered urgent protective actions in a nuclear or radiological emergency are evacuation, decontamination of individuals, sheltering, respiratory protection, iodine prophylaxis and restriction of the consumption of potentially contaminated foodstuffs.

Warning point. A contact point that is staffed or able to be alerted at all times for promptly responding to, or initiating a response to, an incoming notification (meaning (2)), warning message, request for assistance or request for verification of a message, as appropriate, from the iaea.

Whole body dose: see total effective dose.