EPR-Medical Physicists

2020

EMERGENCY PREPAREDNESS AND RESPONSE

Guidance for Medical Physicists Responding to a Nuclear or Radiological Emergency

IAEA

International Atomic Energy Agency

IAEA SAFETY STANDARDS AND RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety. The publication categories in the series are **Safety Fundamentals**, **Safety Requirements** and **Safety Guides**.

Information on the IAEA's safety standards programme is available on the IAEA Internet site

https://www.iaea.org/resources/safety-standards

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at: Vienna International Centre, PO Box 100, 1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by email to Official.Mail@iaea.org.

RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety in nuclear activities are issued as **Safety Reports**, which provide practical examples and detailed methods that can be used in support of the safety standards.

Other safety related IAEA publications are issued as **Emergency Preparedness and Response publications, Radiological Assessment Reports**, the International Nuclear Safety Group's **INSAG Reports**, **Technical Reports** and **TECDOCs**. The IAEA also issues reports on radiological accidents, training manuals and practical manuals, and other special safety related publications.

Security related publications are issued in the **IAEA Nuclear Security Series**.

The **IAEA Nuclear Energy Series** comprises informational publications to encourage and assist research on, and the development and practical application of, nuclear energy for peaceful purposes. It includes reports and guides on the status of and advances in technology, and on experience, good practices and practical examples in the areas of nuclear power, the nuclear fuel cycle, radioactive waste management and decommissioning.

GUIDANCE FOR MEDICAL PHYSICISTS RESPONDING TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ANTIGUA AND BARBUDA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHAMAS
BAHRAIN
BANGLADESH
BARBADOS
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA, PLURINATIONAL STATE OF
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BRUNEI DARUSSALAM
BULGARIA
BURKINA FASO
BURUNDI
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
CONGO
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DJIBOUTI
DOMINICA
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ESWATINI
ETHIOPIA
FIJI
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GRENADA
GUATEMALA
GUYANA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LAO PEOPLE'S DEMOCRATIC REPUBLIC
LATVIA
LEBANON
LESOTHO
LIBERIA
LIBYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORTH MACEDONIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
PAPUA NEW GUINEA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
RWANDA
SAINT LUCIA
SAINT VINCENT AND THE GRENADINES
SAN MARINO
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
TOGO
TRINIDAD AND TOBAGO
TUNISIA
TURKEY
TURKMENISTAN
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VANUATU
VENEZUELA, BOLIVARIAN REPUBLIC OF
VIET NAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

EPR-MEDICAL PHYSICISTS (2020)

GUIDANCE FOR MEDICAL PHYSICISTS RESPONDING TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

ENDORSED BY THE
AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE,
EUROPEAN ASSOCIATION OF NUCLEAR MEDICINE,
INTERNATIONAL ASSOCIATION OF RADIOPATHOLOGY,
INTERNATIONAL FEDERATION OF RED CROSS AND RED CRESCENT SOCIETIES,
INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS,
AND LATIN AMERICAN ASSOCIATION OF SOCIETIES
OF NUCLEAR MEDICINE AND BIOLOGY

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2020

For further information on this publication, please contact:

Incident and Emergency Centre
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
Email: Official.Mail@iaea.org

GUIDANCE FOR MEDICAL PHYSICISTS RESPONDING
TO A NUCLEAR OR RADIOLOGICAL EMERGENCY
IAEA, VIENNA, 2020
EPR-MEDICAL PHYSICISTS (2020)
ISSN 2518–685X

Printed by the IAEA in Austria
June 2020

FOREWORD

The medical management of individuals involved in a nuclear or radiological emergency requires specially trained personnel. Lessons learned from previous events have demonstrated that caring for these individuals calls for a multidisciplinary team of health care professionals if the response is to be effective.

All hospitals offering medical radiation services (e.g. radiology, radiotherapy, nuclear medicine) have medical physicists who are part of the clinical team, with special responsibility for the proper and safe application of ionizing radiation. Using this reservoir of radiation protection experts in emergency and preparedness teams is good medical practice.

Clinical medical physicists working in hospitals have in-depth knowledge of radiation dosimetry, dose reconstruction and dose measurement procedures. They constitute a unique group of professionals who, with the appropriate training, can provide effective support for emergency preparedness and response activities.

Some sections of this publication were developed under the NA/21 Project supported by the Government of Japan within the IAEA Action Plan on Nuclear Safety, in cooperation with the International Organization for Medical Physics.

This publication has been endorsed by the American Association of Physicists in Medicine, European Association of Nuclear Medicine, International Association of Radiopathology, International Federation of Red Cross and Red Crescent Societies, International Organization for Medical Physics and Latin American Association of Societies of Nuclear Medicine and Biology.

The IAEA officers responsible for this publication were E.D. Herrera Reyes of the Incident and Emergency Centre, and T. Berris and A. Meghzifene of the Division of Human Health.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

To reduce the impact of a nuclear or radiological emergency, it is necessary for the experts involved to be adequately and continuously trained at regular intervals. In addition to their normal duties, medical physicists (MPs) employed in hospitals may also be responsible for radiation protection aspects, including providing support to a response to nuclear or radiological emergencies. To this end, a special training programme for MPs was developed under the auspices of the IAEA that focuses on the specific requirements, roles and responsibilities of clinically qualified medical physicists (CQMPs) [1]. However, there is a lack of specific training for MPs in the area of emergency preparedness and response (EPR) to nuclear or radiological emergencies. In an effort to promote effective EPR, the IAEA organized workshops to share experience and contribute to the involvement of MPs supporting the response to nuclear or radiological emergencies [2].

1.2. OBJECTIVE

Depending on local and national conditions, the MP may be requested to serve as a member of the emergency response team, which may require this person fulfilling different functional roles. The objective of this publication is to guide the trained CQMP [1] to act appropriately in a nuclear or radiological emergency and ensure that an efficient and coordinated contribution is made to the management of such an emergency. The knowledge of the CQMP can be vital in the preparedness and response to nuclear or radiological emergencies.

1.3. SCOPE

This publication focuses on guiding MPs in their response to operational conditions during radiological emergencies. To facilitate a quick response, a 'pocket guide' (EPR-Pocket Guide for Medical Physicists 2020 [3]) has been produced summarizing most of the concepts presented in this publication. As part of this package, standardized training materials were also developed taking as a basis the various IAEA workshops in this area.

1.4. STRUCTURE

This publication is organized into sections based on a functional EPR structure. The sections present basic concepts: the relevance of the notification and contact points; radiation protection concepts; activities related to specific roles of the MP in the preparation of facilities, dose assessment; and concepts related to effective communication. In the last part, a syllabus is presented containing information for the training of MPs. The appendices contain detailed information to complement the main sections of the publication.

2. DEFINITIONS AND BASIC CONCEPTS

2.1. DEFINITION OF A NUCLEAR OR RADIOLOGICAL EMERGENCY

As defined in IAEA Safety Standards Series No. GSR Part 7 [4], an emergency is:

> "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."

A nuclear or radiological emergency is [4]:

> "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.”

2.2. FRAMEWORK PROVIDED BY NATIONAL HEALTH AUTHORITIES

At the national level, the response to a nuclear or radiological emergency is integrated in a national emergency response plan. This national framework can ensure that planning for medical responses to nuclear or radiological emergencies exists, and that the facilities that manage the medical consequences of such emergencies have staff trained in the necessary skills. This preparedness also includes the development of guidance and protocols, exercises, and drills to prepare the facility and staff to respond to emergency scenarios. These exercises need to be performed with appropriate regularity in order to train staff and provide an effective response if an emergency occurs.

2.3. ROLES OF THE MEDICAL PHYSICIST IN A NUCLEAR OR RADIOLOGICAL EMERGENCY

Qualified MPs will have completed training in radiation protection and may contribute as experts in this field owing to their experience in dose assessment, the handling of radioactive material and the assessment of exposure in a hospital environment. IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards [5], and most training programmes for MPs, require specific training in preparedness for a nuclear or radiological emergency.

In the event of a nuclear or radiological emergency, the CQMP can join the emergency response teams, following assigned roles and responsibilities. Depending on his or her level of expertise, the MP may be asked to perform one or several roles, as described below:

(a) **Radiological assessor (RA)**: As a qualified expert in radiation dosimetry, the MP can fulfil the function of an RA [6].
(b) **Scientific and technical advisor**: Because the MP usually acts as a radiation protection officer, he or she can give advice on matters related to a nuclear or radiological emergency.
(c) **Trainer in radiation protection**: The MP typically provides regular training in his or her own clinical environment. In addition, those MPs who are specifically trained in nuclear or radiological emergencies can perform training inside and outside their hospital [7]. During the emergency, the trainer will be able to provide quick briefings on radiation protections for the emergency teams.

In a clinical environment the MP may be primarily involved in those nuclear or radiological emergencies that involve exposure from radiation generating devices such as accelerators or X ray generators, but also derived from exposures to radioactive material such as internal or external contamination. This role may not be limited to the clinical environment, and participation of the CQMP can be also expected during a nuclear or radiological emergency that may occur at nuclear power plants, nuclear fuel cycle or storage facilities, or at industrial facilities producing radiopharmaceuticals. A CQMP may also be involved in incidents related to the military use of radioactive devices, the malicious use of radioactive sources, uncontrolled, damaged, lost or stolen radioactive sources, and failure of medical devices that contain radioactive sources [8].

2.4. OVERVIEW OF THE FRAMEWORK OF COLLABORATION

CQMPs specially trained to respond to emergencies in their own field of competence, i.e. measurement of radiation and dose assessment, can be integrated into a nuclear or radiological emergency response team according to the national plan for such emergencies. Thus, the framework of collaboration can consider action at different levels, including actions in the clinical environment or outside it, such as:

- ***Pre-hospital level.*** The MP may play a role, specifically, supporting the triage teams and decontamination actions. The response to a nuclear or radiological emergency requires the involvement of local, regional, national and international organizations. The MP may collaborate with authorities, specialized agencies and technical experts within the framework of a national plan. These triage teams and decontamination teams may not necessarily be located at the hospital, but can still be part of first response teams or wait in a reception centre.
- ***Hospital level.*** The role of CQMPs in emergencies has to be well understood and supported by the hospital management, as well as other health care professionals and technical staff. The MP may be requested to provide information on nuclear or radiological emergencies and advice and training to all medical staff in various departments of the hospital — for example, emergency medicine, surgery, haematology, anaesthesiology — and also to supporting staff (e.g. administrative staff, security and cleaning services staff). For efficiency, the MP may be assisted by other specialists, such as dosimetrists, properly trained for emergency preparedness.

It is important to integrate the MP into the preparedness stage in order to define their roles and actions in the planning at local, regional and national levels.

3. INCIDENT COMMAND SYSTEM AND NOTIFICATION

3.1. INCIDENT AND COMMAND SYSTEM

The incident command system (ICS) for emergency response consolidates decision making in a single incident commander. All activities and functions report to the incident commander. The result of having an ICS in place is that it enables responders from different organizations, ministries and agencies to work together. MPs are expected to participate in the response efforts as part of an ICS. It is therefore important for them to have a fundamental understanding of how this mechanism works.

A key feature of an ICS is that the size of the response organization is scalable to the needs of the specific emergency. The types of functions can also be varied according to these specific needs. For example, not all of the groups may be required for a small emergency, so these functions may be combined [9].

One of the main advantages of an ICS is that it allows different disciplines and functions to work together in a unified structure with unified decision making. For public information, this also facilitates coordination between different organizations that may be involved in responding to a nuclear or radiological emergency, such as ministries responsible for radiation protection, health, the environment and food. For example, during an accident involving a nuclear power plant, the public information group may include representatives from the environment ministry, the health ministry, and civil protection, as well as the regulatory authority. By working together as one information team, an ICS helps to coordinate information and communication activities between responding organizations. Figure 1 provides an example of an ICS structure [9].

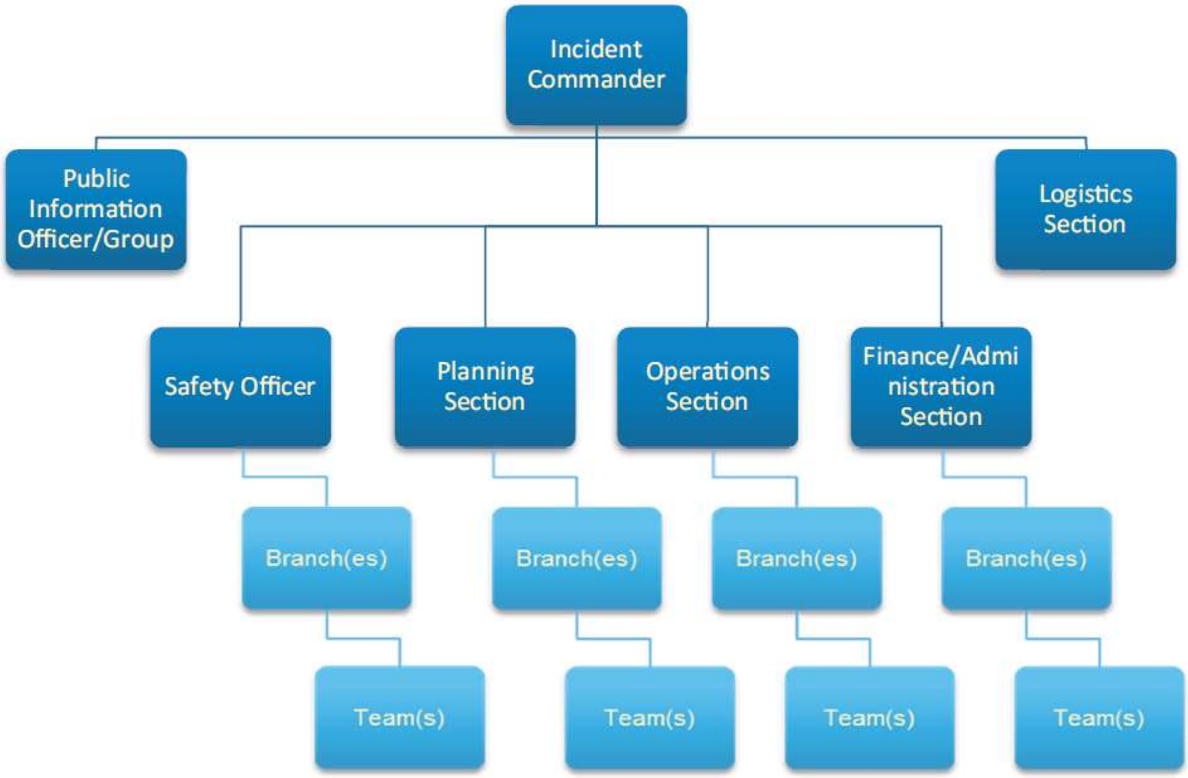


FIG. 1. Basic structure of an ICS (adapted from Ref. [9]).

3.2. CHAIN OF COMMAND MEDICAL PHYSICISTS

If the hospital has an emergency response plan in place that considers nuclear or radiological emergencies, the role of the MPs and the chain of command to be followed under the ICS needs to be specified in that plan. If the hospital does not have such detailed plans, it is important for each MP to ask the following questions:

(a) **Whom am I reporting to?** In many cases the MP's supervisor/manager for daily routine hospital activities may not be the person designated to manage the MP's activities during a nuclear or radiological emergency response;

(b) **Whom am I responsible for?** The role and responsibilities assigned to MP should be clearly defined in the chain of command. The role of the MP might be related to activities in the area of radioprotection and safety of personnel, patients or technical activities of specific teams (such as the decontamination or dose assessment teams).

3.3. NOTIFICATION CHANNELS

In many countries, there is an emergency system that is followed when an emergency occurs. Local, regional or national authorities may be involved depending on the magnitude of the emergency. It is important for the notification channels to be clearly specified in any plan to respond to radiation emergencies. In some countries, it is not only the institutions and organizations under the ministry of health that are involved; in most cases the national competent authority, the regulatory body for nuclear or radiological purposes, is also involved. To define these notification channels is critical in the preparedness of the response to nuclear or radiological emergencies, which may also involve international official notifications (i.e. to the IAEA or other organizations). Since there are usually a number of organizations involved in the response to nuclear or radiological emergencies, it is important to include in the emergency plan contact information of the parties involved.

4. ACTIVITIES RELATED TO PREPAREDNESS

4.1. ROUTINE ACTIVITIES AS A BASIS TO SUPPORT THE MEDICAL RESPONSE

For an effective medical response to nuclear or radiological emergencies, the sequence of actions needs to be in line with the potential consequences of the emergency [8]. Therefore, the identification of potential risks to respond to and capacities to respond at the preparedness stage is essential. Some of the activities performed on a daily basis by the CQMP at the hospital can be of importance during the response to nuclear or radiological emergencies. The integration of the CQMP into EPR teams can provide a major impact, especially at the hospital level. These activities include:

(a) Dose assessment (for clinical purposes);
(b) Radiological surveys using radiation detection instrumentation in the hospital environment;
(c) Screening of contamination. Some CQMPs may have experience in the decontamination of patients (i.e. those related to nuclear medicine departments);
(d) Training of other personnel in radiation protection;
(e) Role as RAs at the hospital level [8].

Their main task will be to support the medical response and radiation protection activities at the hospital level. The CQMP may also be responsible for the personal radiation protection of the health care or other EPR teams involved in emergencies.

4.2. TRAINING

Successful response depends on successful training before a response is needed (preparedness stage). The CQMP responsible for supporting the medical response requires training and needs a trained team with adequate resources to support the response. Besides the training received in exercises, the participants will need additional instruction on any specific hazards expected during any emergency. The MP’s skills are necessary to set up an appropriate system and to maintain its effectiveness in exercises.

The training should not be limited to radiation protection concepts. Through routine exercises, teams should be also trained on when and how to use protective equipment (how to decontaminate it and clean it, if necessary) [10]. They will also have to recognize faulty equipment and hazards which may arise from use of the equipment [10]. Training needs to include the correct use of survey meters, as well as how to ensure that the equipment is responding as planned.

4.3. CRITERIA FOR EXPOSURE

On the basis of the outcome of the justification and the optimization of the protection strategy for a nuclear or radiological emergency, national generic criteria for taking protective and other response actions, expressed in terms of projected dose or dose that has been received, should be developed, with account taken of the generic criteria [4]. These criteria are based on the estimation of doses that might be projected or received from situations derived from internal and external exposures to ionizing radiation:

(a) External exposure occurs when an individual is exposed to radiation from a source outside the body. Personnel involved in the mitigation of an emergency or members of the general public may receive external doses ranging from low to very high, including lethal doses. External exposure could be for the whole body, partial or localized. One of the most frequent consequences of localized external exposure is local radiation burn to the leg or hand of a radiographer from mishandling a sealed source, or to a member of the general public who has gained possession of a lost or stolen sealed source [8].

(b) Internal exposure to radiation from a source within the body occurs when radioactive material is deposited in the body by inhalation, ingestion or absorption by intact skin or wounds (internal contamination). The intake of radionuclides can be determined by in vitro and in vivo bioassay techniques.

External contamination of individuals may occur when radioactive material comes in contact with the skin, hair, nails and clothes of an individual, for whom the possibility of internal contamination needs to be evaluated. Contamination of individuals may occur when radioactive material (solid, liquid or gas) is released to the environment and comes in contact with them . Workers, response personnel and members of the general public may become externally or internally contaminated following such a release of radioactive material. Although most realistically expected instances of contamination result in little or no acute medical consequences, high levels of external contamination with beta radionuclides could lead to severe radiation burns. High level of internal contamination could result in a lethal dose and the death of the person [8].

Clear criteria need to be established to take the appropriate actions. The IAEA generic criteria are levels which can be divided into projected doses or received doses at which protective and other response actions should be taken. The term 'generic criteria' as defined here relates to EPR only [4]. Tables 1 and 2 provide guidance for projected or received doses, respectively.

TABLE 1. GUIDANCE VALUES FOR RESTRICTING EXPOSURE OF EMERGENCY WORKERS [4]

Tasks	Guidance value*		
	$H_p(10)$ **	E***	AD_T+
Life-saving actions	<500 mSv	<500 mSv	$<\frac{1}{2}AD_{T,Table\ 2}$
	This value may be exceeded — with due consideration of the generic criteria in Table 2 — under circumstances in which the expected benefits to others clearly outweigh the emergency worker's own health risks, and the emergency worker volunteers to take the action and understands and accepts these health risks		
Actions to prevent severe deterministic effects and actions to prevent the development of catastrophic conditions that could significantly affect people and the environment	<500 mSv	<500 mSv	$<\frac{1}{2}AD_{T,Table\ 2}$
Actions to avert a large collective dose	<100 mSv	E<100 mSv	$<\frac{1}{10}AD_{T,Table\ 2}$

* These values are set to be two to ten times lower than the generic criteria in Table 2, and they apply to:

— The dose from external exposure to strongly penetrating radiation for $H_p(10)$. Doses from external exposure to weakly penetrating radiation and from intake or skin contamination should be prevented. If this is not feasible, the effective dose and the RBE weighted absorbed dose to a tissue or organ should be

limited to minimize the health risk to the individual, in line with the risk associated with the guidance values given here.
— The total effective dose E and the RBE weighted absorbed dose to a tissue or organ AD_T via all exposure pathways (i.e. both the dose from external exposure and the 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 $H_p(d)$, where d = 10 mm.

*** Effective dose.

\+ RBE weighted absorbed dose to a tissue or organ. Values of RBE weighted absorbed dose to a tissue or organ given in Table 2.

TABLE 2. GENERIC CRITERIA FOR DOSES RECEIVED WITHIN A SHORT PERIOD OF TIME FOR WHICH PROTECTIVE ACTIONS AND OTHER RESPONSE ACTIONS ARE EXPECTED TO BE TAKEN UNDER ANY CIRCUMSTANCES IN AN EMERGENCY TO AVOID OR TO MINIMIZE SEVERE DETERMINISTIC EFFECTS [4, 11]

Acute external exposure (<10 h)		
$AD_{\text{red marrow}}$[a]	1 Gy	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_{fetus}	0.1[b] Gy	
AD_{tissue}[c]	25 Gy at 0.5 cm	
AD_{skin}[d]	10 Gy to 100 cm^2	
Acute internal exposure due to an acute intake (Δ = 30 d[e])		
$AD(\Delta)_{\text{red marrow}}$	0.2 Gy for radionuclides with atomic number Z ≥ 90[f] 2 Gy for radionuclides with atomic number Z ≤ 89[f]	If the dose has been received: —Perform immediate medical examination, medical consultation and indicated medical treatment; —Carry out contamination control; —Carry out immediate decorporation[g] (if applicable); —Conduct registration for longer term medical follow-up; —Provide comprehensive psychological counselling.
$AD(\Delta)_{\text{thyroid}}$	2 Gy	
$AD(\Delta)_{\text{lung}}$[h]	30 Gy	
$AD(\Delta)_{\text{colon}}$[a]	20 Gy	
$AD(\Delta)_{\text{fetus}}$[i]	0.1[b] Gy	

a $AD_{\text{red marrow}}$ 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 At 0.1 Gy, there would be only a very small probability of severe deterministic effects to the fetus only during certain periods post-conception (e.g. between 8 and 15 weeks of in utero development), and only if the dose is received at high dose rates. During other periods post-conception and for lower dose rates, the fetus is less sensitive. There is a high probability of severe deterministic effects at 1 Gy. Therefore, 1 Gy is used as the generic criterion for doses to the fetus received within a short period of time: (i) in the hazard assessment (see Ref. [4] para. 4.23), to identify facilities and activities, on-site areas, off-site areas and locations for which a nuclear or radiological emergency could warrant precautionary urgent protective actions to avoid or to minimize severe deterministic effects; (ii) for identifying situations in which exposure is dangerous to health; and (iii) for making arrangements (see Ref. [4] para. 5.38) for applying decisions on urgent protective actions and other response actions to be taken off-site to avoid or minimize the occurrence of severe deterministic effects (e.g. establishing a precautionary action zone).

[c] 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).

[d] 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 surface).

[e] $AD(\Delta)$ is the RBE weighted absorbed dose delivered over a period of time Δ by the intake (I_{05}) that will result in a severe deterministic effect in 5% of exposed individuals. This dose is calculated as described in appendix I of Ref. [11].

[f] Different generic criteria are used to take account of the significant difference in RBE weighted absorbed dose from exposure at the intake threshold values specific for these two groups of radionuclides.

[g] Decorporation is the action of the biological processes, facilitated by chemical or biological agents, by means of which incorporated radionuclides are removed from the human body. The generic criterion for decorporation is based on the projected dose without decorporation.

[h] For the purposes of these generic criteria, 'lung' means the alveolar–interstitial region of the respiratory tract.

[i] For this particular case, 'Δ' refers to the period of in utero development of the embryo and fetus.

4.4. OVERVIEW OF THE RESPONSIBILITIES OF THE MEDICAL PHYSICIST

In order to be implemented effectively, the emergency medical response needs to be planned and organized and requires adequate resources, including staff, personal protective equipment (PPE), contamination control supplies and calibrated operational survey meters [8].

The MPs need to communicate effectively with the EPR teams, and also ensure that they receive instructions about their roles and responsibilities and about whom they will report information to during the response. The responsibilities of the MP regarding radiation protection include the following:

(a) Assess patient dose due to internal and/or external irradiation and provide advice on the clinical care of patients.
(b) Promote the safety of patients and workers and a safety culture as the cornerstone of limiting radiation exposure and the spread of contamination in a nuclear or radiological emergency.
(c) Promote the use of universal standard precautions as the minimum level of protection when providing care for patients.
(d) Assess what personal protective measures are indicated given the available resources.
(e) Implement appropriate contamination control measures.
(f) Monitor radiation exposure of the staff.
(g) Keep staff informed and provide frequent updates to team members. Help in the preparation of messages directed at communicating with patients, their families and the general public to the required extent, in coordination with the team responsible for communication.
(h) Know the signs of worker stress.
(i) Remind workers that proper use of PPE prevents them from being contaminated.
(j) Remind workers that time, distance and shielding can reduce exposure to radiation.
(k) Inform pregnant workers about the risks associated with response efforts, and exclude them from the team supporting the response if the staff dose is expected to exceed the limits for pregnant workers.
(l) Remind workers not to eat or drink while participating in the response.
(m) Remind workers to monitor electronic personal dosimeters (EPDs) and to request assistance when removing PPE.

4.5. PERSONAL PROTECTION AND RADIATION MONITORING

MPs may be responsible for providing information to hospital staff before their intervention during a nuclear or radiological emergency. Key points to remind workers of in a radiation safety briefing are the following:

(a) Providing medical emergency care is the most important activity. Stabilizing a patient with life-threatening conditions should not be delayed because of the presence of contamination.
(b) Proper use of PPE can prevent them from being contaminated.
(c) Time, distance and shielding can reduce exposure to radiation.
(d) Pregnant workers should be informed about the risks associated with response efforts and excluded from the team supporting the response if the staff dose is expected to exceed limits for pregnant workers.
(e) Remind workers not to eat or drink while participating in the response.
(f) Remind workers to monitor EPD and to request assistance when removing PPE.

4.6. PERSONAL PROTECTIVE EQUIPMENT AND SURVEYING RESOURCES

Depending upon the availability of resources, every facility and hospital should have a standard inventory of protective equipment as described in Tables 3 and 4. The amount of equipment used is dependent on the type and scale of the emergency. Resources include protective equipment, contamination control supplies (addressed in Section 4) and operational, calibrated survey meters (Fig. 2). This equipment needs to be stored, inventoried and assessed periodically to ensure that the equipment is operational and readily available when needed.

TABLE 3. SUGGESTED INVENTORY OF PPE, DEPENDING ON LOCAL RESOURCES [8]

Protective clothing	Quantity[a]
Protective suits (jumpsuits or gowns)	20 large and 20 extra large
Gloves (disposable)	100 pairs, various sizes
Surgical caps or bonnets	20
Particulate mask (disposable)	50
Shoe covers	100 pairs, various sizes
Tape	6 rolls, for securing protective clothing
Face shields	6 (wet environment)

[a]Depends on the type and scale of the potential event. There will be a minimum dedicated inventory of supplies. Additional resources can be obtained from the surgical room or other hospital facilities in the event of a large scale response.

TABLE 4. RADIATION DETECTION AND SURVEYING EQUIPMENT

Equipment	Quantity[a]
Electronic dosimeter	4
Individual dosimetry badges (thermoluminescent dosimeters (TLD)), optically stimulated luminescence dosimeters (OSL), etc.)	20
Survey meters for radiation exposure	2
Contamination survey equipment	2
Log book for tracking worker exposures	1
Charts for tracking patient contamination (see Appendices I–III)	20
Batteries	10 of each type needed for EPD and survey meters
Portal monitors (if available)	2

[a] Depends on the size of the event. There will be at least one dosimeter for each radiological response team member. Additional resources may be available from the government authorities responsible for emergency response or from the radiology departments of the hospital.

FIG. 2. Radiation measurement instruments prepared for operational use. From left to right: scintillation survey meter probe; alpha particle surface contamination detector; Geiger–Müller survey meter and ionizing chamber. The plastic covers prevent contamination of the instruments [7].

4.7. ADDITIONAL HAZARDS

In addition to radiological risks, the use of PPE can also create other problems and exacerbate hazards for those involved [10], for instance, a worker's field of vision may be reduced while wearing protective clothing, vocal communication may be restricted and head covering may impair hearing. Such conditions increase the worker's vulnerability to normal hazards and necessitate increased awareness and care [10]. The RA needs to consider heat exhaustion among workers wearing PPE. Regular scheduled breaks need to be taken to monitor the status of workers. Chemical and biological hazards may exist in the response environment. The RA has to evaluate and plan to minimize these hazards.

4.8. PROCEDURES

4.8.1. Procedures for donning protective clothing

The steps for wearing protective equipment are as follows [8]:

(1) Use universal precautions. Dress in protective clothing (surgical clothing, including scrub suit, gown, mask, cap, eye protection and gloves).
(2) Put on shoe covers.
(3) Put on dosimeter.
(4) Put on trousers. Tape the trousers to shoe covers.
(5) Put on a surgical gown. Tie and tape gown openings.
(6) Put on surgical cap and face mask.
(7) Put on inner gloves. Seal gloves to gown sleeves by tape. Gloves will be under the arm cuff.
(8) Put on splash (face shield) protector.

Fold-over tabs at the end of each taped area will aid removal. The purpose of protective clothing is to keep bare skin and personal clothing free of contaminants. This protective clothing is effective in stopping alpha particles and some beta particles, but not gamma rays. Lead aprons, such as those used in the X ray department, are not recommended since they give a false sense of security — they will not stop most gamma rays. Any member of the team using liquids for decontamination has to wear a waterproof apron. Shoe covers should also be waterproof. For taping all open seams and cuffs, use masking or adhesive tape. EPDs will be attached to the outside of the surgical gown at the neck, where they can be easily removed and read. If available, a film badge or other type of dosimeter can be worn under the surgical gown.

4.8.2. Procedures for personnel monitoring

The following is a checklist for personal monitoring:

(a) Identify the resources needed based on the activities to be performed.
(b) Recommend the assignment of EPD and individual badge dosimeters (TLD, OSL, etc.) and log serial numbers into the log book if used.
(c) TLDs will be worn close to the centre of the body beneath the protective clothing.
(d) Survey instruments will be checked in a normal background area prior to use. Consider appropriate methods to prevent instrument contamination (Fig. 2).
(e) Periodically monitor team members' hands to prevent cross-contamination.
(f) Perform frequent surveys of the work area.
(g) Survey the workers prior to their leaving the restricted area, and log the results.
(h) Provide assistance for the safe removal of protective clothing and confirm by survey that the worker is not contaminated.

The resources will depend on the size of the event. There will be a minimum inventory of supplies. Additional resources can be obtained from the surgical room or other hospital facilities in the event of a large scale response.

4.8.3. **After actions**

The RA completes the action from the response once the resources are returned to inventory. Supplies have to be replenished and the operability of the equipment should be confirmed. Workers should be provided with reports on radiation exposure measurements.

5. ACTIVITIES RELATED TO THE RESPONSE

5.1. ROLES AND RESPONSIBILITIES OF THE MEDICAL PHYSICIST

The roles and responsibilities of the MP in support of a nuclear or radiological emergency response can be divided into two phases.

5.1.1. During the emergency (response phase)

The MP responds and operates under the incident commander. Upon notification that a nuclear or radiological emergency has occurred, patients may start arriving at the hospital. The MP assists in implementing the hospital emergency response plan and ensures that the facility is protected. He or she also provides briefings to the team on radioprotection issues and what may occur during the handling of contaminated patients. The MP also ensures that proper physical arrangements are made to receive and expeditiously process potentially contaminated patients with minimal disruption to the hospital's non-radiological emergency operations during and after the incident.

5.1.2. After the emergency (recovery phase)

The MP should lead the radiological survey of the hospital areas and the decontamination of those areas if needed. He or she should also work with relevant national or local authorities to dispose of any radioactive waste stored at the hospital, and brief hospital management and hospital staff before the facility returns to normal and routine operations (see Section 5.5.2 for more information regarding waste management).

5.2. PREPARATION AND PROTECTION OF AREAS

Preparing and protecting the receiving areas in the hospital or facilities designated to receive contaminated individuals should be organized by the CQMP. The objectives of these activities are the following:

(a) To receive and process exposed and/or potentially contaminated individuals safely, efficiently and with minimum disruption of routine or emergency operations unrelated to the nuclear or radiological emergency;
(b) To safely and effectively manage the potential exposure of radiation to staff and other patients, as well as the effective management of potentially contaminated waste;
(c) To return the hospital or facility to normal operations soon after the emergency is terminated.

5.3. KEY CONSIDERATIONS

The procedures described here need to be adapted to reflect national guidelines, plans and policies, as well as local conditions and hospital conditions and capabilities [8]:

(a) The hospital staff, including the MP, have to operate under an ICS.
(b) Life-saving medical care for a patient with life-threatening conditions should not be delayed even if the presence of contamination is detectable.
(c) Requests for outside assistance should be coordinated with the hospital emergency management officials (or incident commander) and transmitted through proper and established channels of communication with local or national authorities.
(d) Hospitals should be prepared for three groups of people arriving from a nuclear or radiological emergency with mass casualties (Note that all three groups could contain individuals who have not been monitored or decontaminated prior to arriving at the hospital.):
    — The 'worried well', who are concerned but not injured. However, they are worried about how they may have been affected; they arrive at the hospital

quickly, on their own initiative. If the staff do not know how to deal with this group, these individuals may divert the hospital's resources and interfere with the treatment of the injured, who will arrive later.

— The injured who are rescued by the public or bystanders. Though clearly injured, these individuals may not be the most severely injured.

— The injured who are rescued by emergency response personnel. These individuals will typically be the most severely injured.

(e) Individuals who are only externally contaminated, but not sick or injured, will be decontaminated at a facility other than the hospital (i.e. reception centres), so that hospital resources are conserved for the sick and injured (Fig. 3).

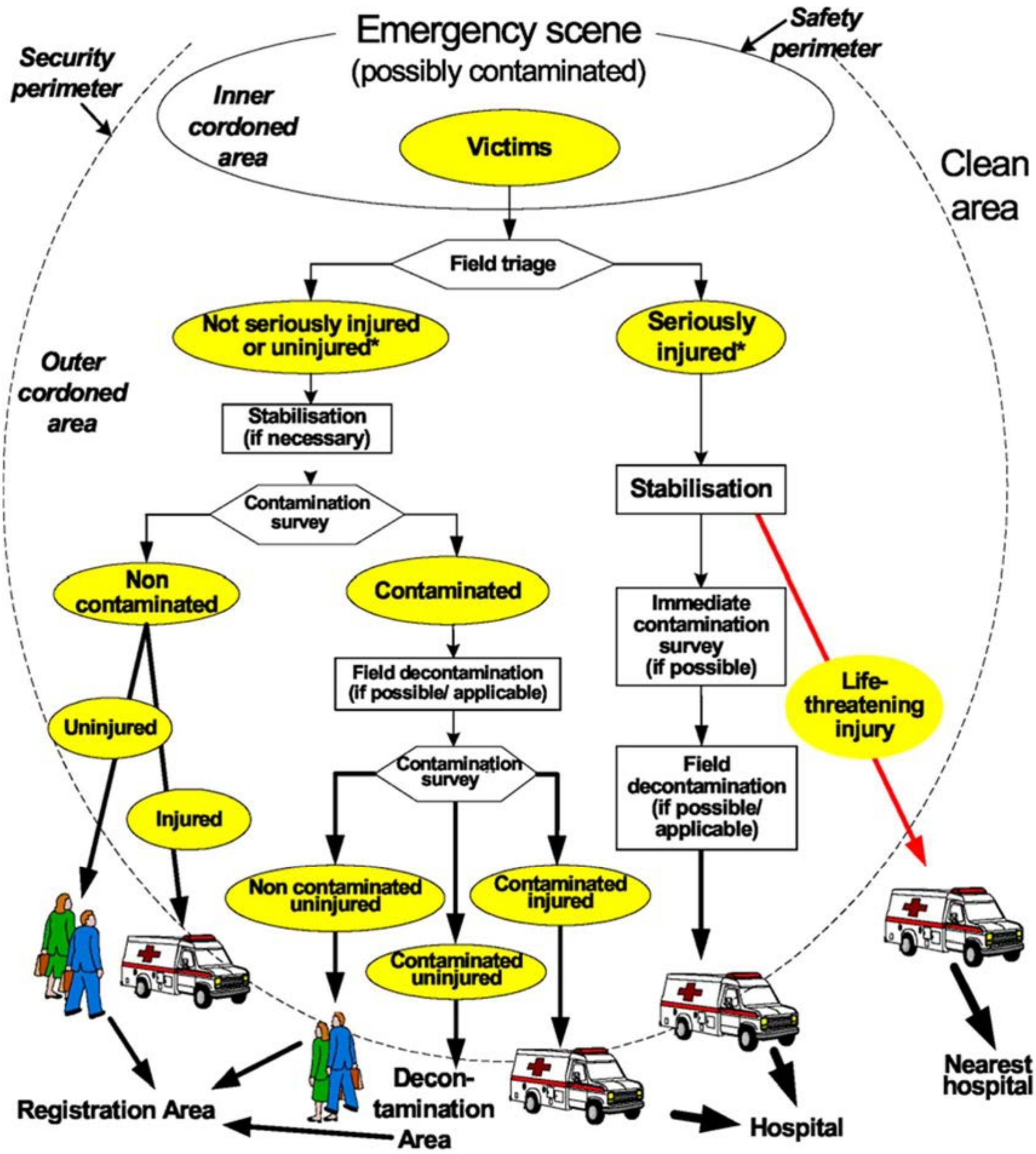


FIG. 3. Diagram of an emergency scene [8].

(f) In cases of potential contamination of a large number of people and the need to monitor them for contamination, it is necessary to establish a reception centre — separate from the hospital — to perform the contamination monitoring. This centre needs trained personnel, radiation monitoring equipment, decontamination facilities and supplies, and manual or digital record keeping supplies. Access to this reception centre should not interfere with access to the hospitals accepting casualties. Athletics fields, stadiums and community centres could be used as reception centres.

(g) If the emergency is suspected of being a malicious act, it will be necessary to coordinate response activities with law enforcement officials, security teams and forensic experts, to provide protection and security for the hospital, and to preserve evidence.

5.4. EQUIPMENT AND SUPPLIES

The following equipment and supplies are necessary to respond to a nuclear or radiological emergency [12]:

(a) Radiation survey instruments for monitoring patients, and hospital facility areas and equipment, including ambulances. (Use headphones if available; see Section 5.3);
(b) PPE for staff (see Section 3);
(c) Rolls of plastic, wrapping or butcher paper to cover floors and unneeded equipment;
(d) Tape for securing the floor covering (plastic sheeting);
(e) Tape for marking the floor;
(f) Rope or caution tape and warning signs for marking controlled areas clearly;
(g) Large plastic bags for trash;
(h) Large waste containers;
(i) Plastic trash bags for contaminated clothing, tags and marking pens;
(j) Small bags for contaminated personal items with tags or marking pens;
(k) Charts for tracking patient contamination/exposure (see Appendices I–III).

5.5. ACTIONS

These actions are adapted from Ref. [12] (see also Fig. 4):

(a) Operate under the incident commander or the emergency medical manager.
(b) Brief health care staff that the risk from a contaminated person is negligible if they follow the personnel protection guidelines (Section 5.3).
(c) Check and prepare radiation survey meters for use:
— Perform operational checks of the instruments;
— Document background radiation levels;
— Unless the contaminant is an alpha emitter, cover the detector with a plastic sheet or surgical glove to protect the detector from contamination;
— If possible, maintain at least one instrument in the clean area for monitoring.
(d) Collect enough instruments and supplies (e.g. outer gloves, dressings) to change when they become contaminated.
(e) Follow the personnel protection guidelines (Section 5.3).
(f) Follow proposed operational intervention levels (OILs) for decontamination [13].

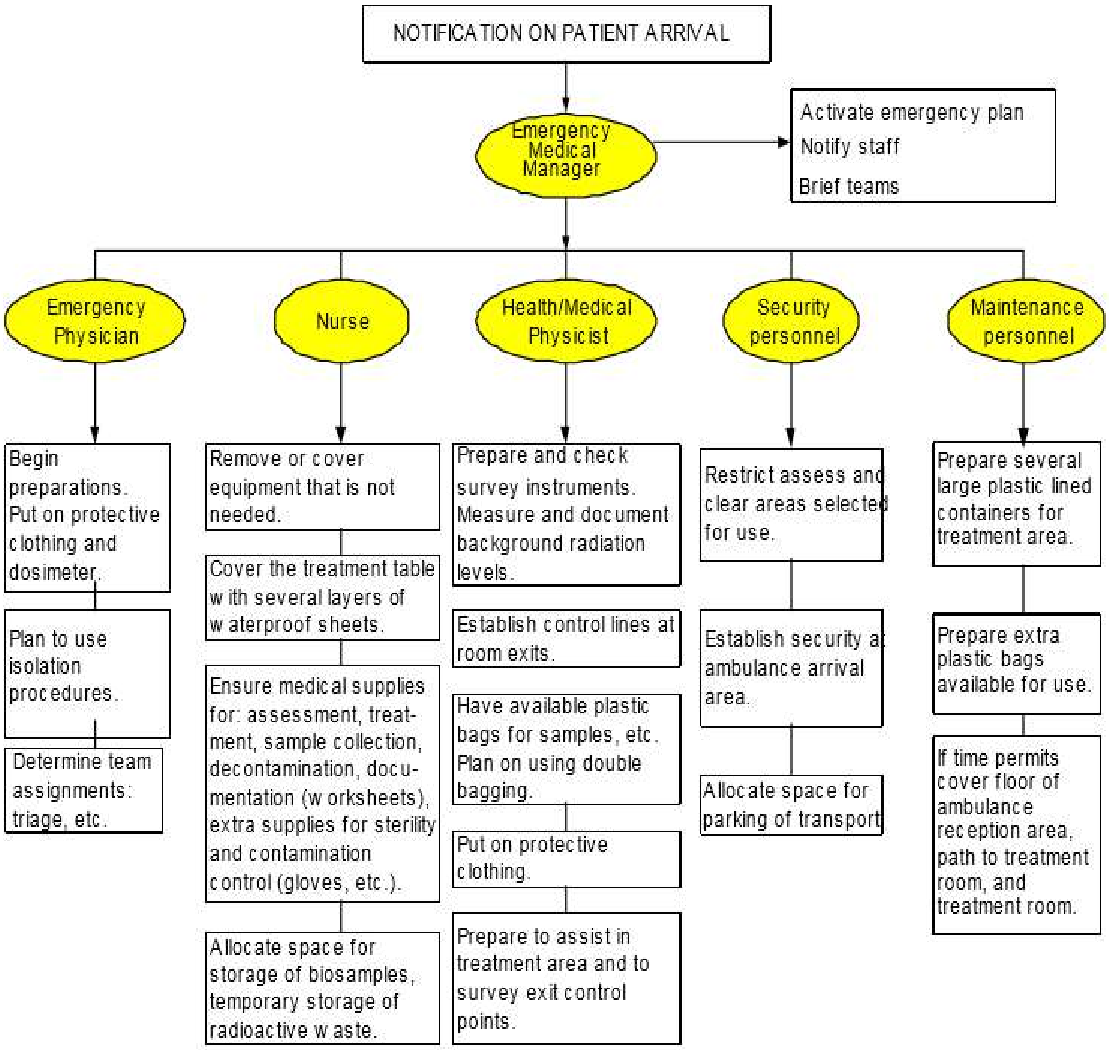


FIG. 4. Schematic outlining preparations for contamination control by the hospital emergency department response team [8].

5.5.1. Radiological control of areas

This section is adapted from Refs [8, 12] (see also Fig. 4):

(a) Law enforcement should redirect the 'worried well' persons, i.e. those who are concerned, but not injured, to the secondary location (i.e. reception centre), as established by the resource coordinator, for monitoring and reassurance.

(b) Prepare and designate an **ambulance reception area** and **treatment area** for receiving casualties according to the hospital plan for medical response to nuclear or radiological emergencies.

(c) Each hospital must consider its individual situation and respective facility design. Appendix I presents sample set-ups for hospital reception areas for emergencies resulting in several casualties or mass casualties.

(d) Make a path from the ambulance entrance to the hospital entrance using rolls of plastic sheeting about 1 m wide. Cover the floor.

- Ordinary cloth sheets or square absorbent pads can be used if paper is unavailable;
- Tape the floor covering securely to the floor;
- Plastic sheets may often be slippery (especially if wet).Remember that placing floor covering should not delay any urgent or emergency medical care.

(e) Rope off and mark the route to prevent unauthorized entry.

(f) Re-route the traffic of individuals or patients not involved in the nuclear or radiological emergency, as appropriate, e.g. direct other medical emergencies to another hospital entrance.

(g) Select a **controlled treatment area** near an outside entrance (if possible):
- Set up an area large enough to handle the anticipated number of patients;
- Clear this area of visitors and individuals or patients not involved in the nuclear or radiological emergency;
- Remove or cover equipment that will not be needed (for example, portable X ray machines).

(h) Restrict access to the **controlled treatment area**.

(i) Designate a buffer zone or secondary control line for added security.

(j) Make provisions to monitor anyone or anything leaving the controlled area.

(k) Prepare several large plastic-lined waste containers, plastic bags of varying sizes, labels for personal effects, and warning labels and signs.

(l) Prepare the decontamination room of the treatment area if one has been previously designated. Otherwise, designate a **decontamination room** near the entrance to the treatment area.

(m) Establish a control line at the entrance to the decontamination room. Use wide strip tape to clearly mark the floor at the entrance to the room to differentiate the controlled side (contaminated) from the non-controlled side (uncontaminated).

(n) As the patients arrive:
- Meet the patients at the established ambulance reception area and direct them to the contamination screening area, unless they need immediate medical attention;
- Exposed patients require no special handling while contaminated victims are handled and transported using contamination control procedures. If there is any doubt, assume all victims are contaminated until proven otherwise;
- Ambulance personnel will be surveyed and decontaminated (if necessary) unless the ambulance personnel need to return to the scene immediately for life-saving response actions (see Section 6.1.3. for more information on the decontamination of patients);
- Surveying the ambulance should be delayed until the end of the shift or until all the patients have been transported, if a large number of victims need to be transported;
- Use specified charts for tracking patient contamination/exposure (see Appendices I–III).

(o) Control the spread of contamination:
- Periodically survey staff for possible contamination;
- Ensure that staff are properly surveyed for contamination and decontaminate them when necessary prior to their exiting the contaminated area;
- Survey medical equipment for contamination before removing it from the contaminated area.

In principle, it may be desirable that rooms in the contamination control area have either a separate ventilation system from the rest of the hospital, or a means of preventing the unfiltered exhaust air from the nuclear or radiological emergency area from mixing with air that is distributed to the rest of the hospital. However, there is very little likelihood that contaminants will become suspended in the air and enter the ventilation system, hence, no special precautions are advised.

5.5.2. Waste management

(a) Establish a **waste storage area** where potentially contaminated items such as clothing can be stored. Preferably, this area will be indoors and secured to prevent the spread of contamination, e.g. by wind or rain.
(b) Clearly mark the waste storage area to control access and prevent inadvertent disposal and/or mixing with regular waste.
(c) Collect the following in plastic bags, label them accordingly and take them to the secure designated waste storage area:
   - Clothes collected from potentially contaminated patients or staff;
   - Waste from the decontamination area (gloves, paper towels, used floor covering, etc.);
   - Sheets, blankets and medical supplies used for patient transfer.

(d) Segregate presumptive or confirmed radiological waste.
(e) Make reasonable efforts to minimize the spread of contamination. However, these efforts will not be allowed to delay other response actions.
(f) Collect wastewater in containers for later analysis and disposal, but only if doing so will not delay decontamination efforts and will not interfere with or delay patient treatment.
(g) Final disposal of the nuclear or radiological emergency waste from the hospital has to be consistent with the national policy and strategy for the management of radioactive waste.
(h) If applicable, coordinate handling and processing of this waste with law enforcement officials and forensic experts.

5.5.3. Termination (facility)

At the end of the emergency phase, perform a radiological survey of hospital areas and clean any contaminated areas following established procedures. Do not return the area to normal use until approved by the radiation control authority.

6. EARLY DOSE MAGNITUDE ESTIMATION AND DECONTAMINATION

6.1. PATIENT ASPECTS

Early radiation dose assessment does not need to be overly complicated. The goal of early dose assessment is to determine the magnitude of the radiation dose, not the specific dose. Early dose assessments are used to guide medical management, not assign doses to individuals. Specific dose assignment is carried out at a later phase of the response. Therefore, dose magnitude estimation is an important triage tool to support medical planning for individuals affected by nuclear or radiological emergencies. The intention is to determine the following:

(a) Is there a problem? Is there a cause for medical concern?
(b) If so, how immediate is the need for medical care?

It is essential for the MP to provide the necessary advice so that the treating physician can make the appropriate early medical decisions.

6.1.1. Initial dose estimation for external exposure

Many variables need to be considered when performing initial external dose estimations. Among variables to be considered are: exposure time; distance of the exposed individual from the source; activity of the involved source; potential shielding that may be encountered; the radioisotope concerned. The source activity and isotope, for example, are usually fairly straightforward to identify [14].

In accidental situations it is usually difficult to describe precisely the distance of the affected area of the body from the source, or the exposure time [14]. Due to the inverse square relationship of distance from the source and the associated dose rate relationships, coupled with the extremely high dose rates often encountered, slight inconsistencies in distance estimates and time estimates can have a tremendous impact on dose estimates [14]. Contact dose rates (where the distance is zero) result in much higher dose rates than doses at a distance. It is therefore very important to glean as much information about the incident as possible. It is advisable to gather the information on dose assessment as soon after the incident as possible, before it is forgotten.

An estimate that tends towards the higher realistically expected dose is usually more beneficial for treatment planning purposes than underestimating the dose. All of these issues need to be clarified to the responding health care provider.

While MPs are expected to have an awareness of the relationship between source geometry and dose rates, it is worth emphasizing that the inverse square law ($1/R^2$, where R is the distance from the source) is often the most useful equation when calculating doses at a given distance from a source. It can also be written as in Eq. (1):

$$D = \frac{\Gamma A t}{d^2} \tag{1}$$

where

D	is the dose (assuming negligible difference between the dose rate in air and the dose rate in tissue for dose magnitude estimation purposes);
A	is the source activity;
T	is the exposure time;
d	is the distance;

and Γ is the gamma ray constant, $mSv{\cdot}cm^2{\cdot}h^{-1}{\cdot}MBq^{-1}$ (isotope specific).

The key to using Eq. (1) is the gamma ray constant. Gamma constants for selected commonly encountered sources are as follows (adapted from Ref. [15]):

— Cobalt-60: 3.48 $mSv{\cdot}cm^2{\cdot}h^{-1}{\cdot}MBq^{-1}$;
— Caesium-137: 0.927 $mSv{\cdot}cm^2{\cdot}h^{-1}{\cdot}MBq^{-1}$;
— Iridium-192: 1.24 $mSv{\cdot}cm^2{\cdot}h^{-1}{\cdot}MBq^{-1}$.

Some on-line tools and programmes can provide a good starting point for guiding the initial dose assessment of individuals involved in nuclear or radiological emergencies. One of them is the Rad Pro Calculator (Fig. 5) for initial external dose calculations [16]. This on-line calculator provides beta and gamma dose rate information, with and without shielding, in addition to other dosimetric information. Other calculators, such as the Armed Forces Radiobiology Research Institute (AFRRI) Biodosimetry Assessment Tool (BAT) program [17], or the Radiation

Emergency Medical Management (REMM) dose calculator [18], may also be of use in assessing radiation dose based on biological indicators such as lymphocyte counts and time to emesis. It is important to note that these methods could provide initial guidance on the dose assessment, but they will not replace the standard methods for the dose assessment of individuals.

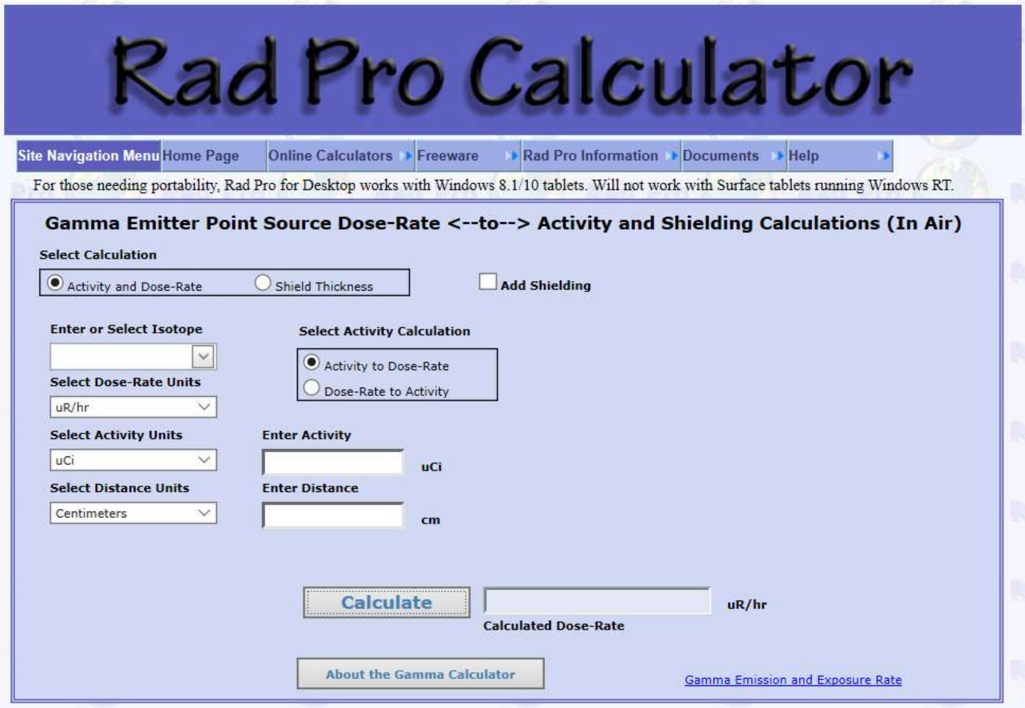


FIG.5. Sample display page for the Rad Pro Calculator [16].

Contact doses — when the involved individual physically touches the source — require evaluation. As mentioned previously, contact dose rates are significantly higher than dose rates at even a small distance from the source. In addition, depending on the source and sealed source capsule, electron build-up should also be considered. For the more commonly encountered gamma emitters (^{60}Co, ^{137}Cs and ^{192}Ir), in a stainless steel capsule, the dose at the skin surface (0.07 mm depth) from contact is due primarily to electrons generated in the source capsule. After the first millimetre in tissue, the primary dose contributor begins to transition to the photons from the gamma emitting radionuclide. Details about common gamma emitters is found in Ref. [14].

It is important for the physician to know which tissues may be primarily affected, in order to detect early clinical manifestations. Similar to other medical physics applications, early assessment of the individuals affected in a nuclear or radiological emergency must take into consideration the radiation type and energy. For beta emitters, nearly all of the energy will likely be deposited in the first few millimetres of tissue; for high energy gamma emitters, the energy deposition peak will be found at a greater depth.

Clinical manifestations and the evolution of individuals will also provide important information for dose assessment, not necessarily present at the early stage of an emergency. Observable radiation induced clinical manifestations are related to threshold doses (Tables 5–7) and usually take time to fully develop [14]. In addition to the threshold effects described in Tables 5 and 6, there are several clinical manifestations (nauseas, vomiting, erythema, etc.) and laboratory tests that will provide valuable information for a first 'medical dose assessment'. One of the most important tests is lymphocyte kinetics, which can be used as an indicator of radiation dose [19, 20].

TABLE 5. SKIN INJURY THRESHOLDS VERSUS ACUTE DOSES
(adapted from Ref. [14])

Dose (Gy)	Effect	Time[a] (time post-exposure)
3	Epilation	14–21 d
6	Erythema	Within hours, then 14–21 d later
10–15	Dry desquamation	2–3 weeks
15–25	Moist desquamation	2–3 weeks
>25	Deep ulceration/necrosis	Dependent upon dose

[a] At higher doses the time to the onset of signs/symptoms may be reduced.

TABLE 6. THRESHOLDS FOR ACUTE RADIATION SYNDROMES
(adapted from Ref. [14])

Dose	Syndrome	Signs and symptoms*
0–1 Gy	NA	Generally asymptomatic, potential slight drop in lymphocytes later (near 1 Gy)
>1Gy	Haematopoietic	Anorexia, nausea, vomiting, initial granulocytosis and lymphocytopaenia
>6–8 Gy	Gastrointestinal	Early severe nausea, vomiting, watery diarrhoea, pancytopenia
>20 Gy	Cardiovascular/CNS	Nausea/vomiting within first hour, prostration, ataxia, confusion

* At higher doses the time to onset of signs/symptoms may be reduced.

TABLE 7. ABSOLUTE LYMPHOCYTE CONTENT IN THE FIRST TWO DAYS AFTER RADIATION EXPOSURE AND SURVIVAL PROGNOSIS
(adapted from Ref. [8])

Absolute lymphocyte content	Severity of acute radiation syndrome	Survival prognosis
700–1000	Mild	Definite
400–700	Moderate	Probable
100–400	Severe	Possible with special treatment
<100	Very severe	Problematic

Since lymphocytes are sensitive to the effects of ionizing radiation, the slope of the depletion curve after whole body irradiation can be an indicator of the severity of the radiation injury (Table 7). The physician will evaluate the patient's signs and symptoms, comparing them with the information provided by the MP. Discrepancies will be discussed, with an emphasis on the current medical situation (the clinical status of the patient).

Early dose estimations need to be compared with the results obtained by physical dosimetry once they become available. The onset of medical signs and symptoms (or lack thereof) should also be considered [14]. In many cases, the exact dose may never be known. Medical management will require continuing communication between health care and radiation protection professionals to ensure the proper response.

Note that physical dosimetry (TLD, OSLD, etc.) only measures dose to the point where the dosimeter is worn and may not reflect the dose to the affected area of the body. For example, the source could be on the floor, but the dosimeter is being worn on the chest. Thus, it is important that radiation support personnel investigate the circumstances of the incident thoroughly.

Information on the dose assessment of overexposed individuals is also provided by cytogenetic dosimetry, also called biological dosimetry, the gold standard technique being dicentric assay, based on the analysis of solid stained dicentric chromosomes and other chromosomal aberrations in the lymphocytes (Fig. 6) [19]. Chromosome aberration analysis in peripheral lymphocytes of individuals exposed to radiation is currently used as a validated method to estimate absorbed dose [8].

Other important techniques used for dose assessment in radiation emergencies include: premature chromosome condensation (PCC) assay; metaphase spread fluorescence in situ hybridization (FISH) translocation assay; and cytokinesis-block micronuclei assay [11]. However, most of the biological dosimetry assays require several days to provide dose estimations [19].

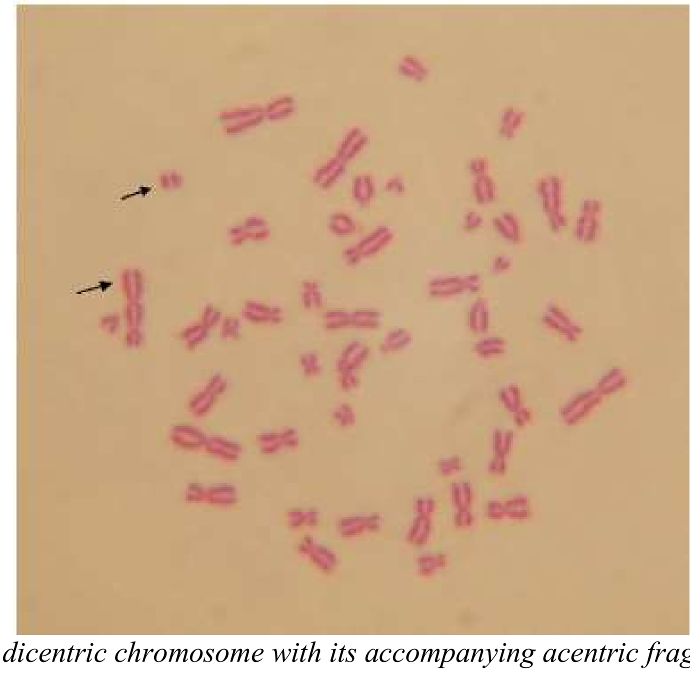


FIG. 6. A dicentric chromosome with its accompanying acentric fragment [19].

The MP should also be aware of potential pitfalls associated with dose estimation in accident situations [14]. As mentioned previously, some of the variables to consider are the accuracy of the exposure times provided and the estimates of the distance from the source. Mock-ups or other means of reconstructing the accident scenario may provide additional information to further refine the dose estimates used to guide medical care [14].

These dose assessment methods are a very important input into the compendium of information that needs to be collected and considered when a nuclear or radiological emergency is investigated [19].

6.1.2. Initial dose estimation for internal exposure

Internal radiation doses can be extremely complicated to determine. There are five potential pathways by which persons may become internally contaminated with radionuclides. This includes: inhalation of radioactive particles or gases; ingestion of radioactive dust and/or contaminated food or water; absorption of radioactive material through wounds; absorption of radioactive material through intact skin; and injection of radioactive material into the body.

Internal contamination with radionuclides has four phases [20]:

(1) **Intake.** The act or processes of taking radionuclides into the body by inhalation or ingestion or through the skin or wounds. The word ‘intake’ also denotes the activity of the radionuclides incorporated into the body in a given time period, or a result of a given event.
(2) **Uptake.** The fraction of an intake entering into systemic circulation.
(3) **Deposition.** The bonding of radionuclides into cells, organs or tissues.
(4) **Decorporation.** The natural or therapy stimulated excretion of the radionuclide.

Internal doses are calculated from the intake: the activity of radioactive material that initially passes the physical confines of the human body. Once the intake is known, biokinetic models are used to calculate the committed doses to various organs or to calculate a committed effective dose [21].

For ingestion and transdermal absorption intakes, bio-analysis of excreta (urine, faeces) or in vivo monitoring is required for dose estimation. Bio-analyses for the identification and quantification of radionuclides in the body are a time consuming procedure (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 [20].

However, early dose magnitude estimation for inhalation or intakes from wounds can be performed fairly easily. Nasal swabs, if taken within the first hour post-intake, represent roughly 10% of the intake [22]. Nasal swabs should be taken at the anterior portion of the nose using a separate swab for each nostril. The results of each swab should be summed for the total nasal swab result. Significant differences between the count rates of each individual swab may indicate cross-contamination (finger, hand, etc.). Note that 10% of the inhalation intake can be estimated through nasal swabs if the swabs are collected within the first hour after intake.

The aim of the assessment of internal contamination is to quantify the incorporation of radioactive material into the body and to estimate the committed effective dose and, where appropriate, the committed equivalent dose to demonstrate compliance with dose limits [20].

Once intake has been estimated, tables found in part XII-B and part XII-D of Ref. [8] can be used to estimate the resulting dose. Comparisons with regulatory dose limits or other acceptable guidelines can then be used to determine the magnitude of the predicted radiation dose estimate.

Wounds are another major intake route from radiation incidents. The Radiation Emergency Assistance Center/Training Site (REAC/TS) has published Dose Coefficients for Intakes of Radionuclides via Contaminated Wounds, from which derived reference levels have been tabulated for various radionuclides [23–26]. This information can be used as a comparison point for dose magnitude estimation.

The United States Centers for Disease Control and Prevention (CDC) have developed an on-line tool to help assess internal doses based on external measurements taken with a number of handheld instruments [27]. More information about early dose magnitude estimation, including examples of the use of these methods, can be found in Refs [14, 28–32].

6.1.3. Decontamination

Once the patient is medically stable, external decontamination should follow a priority order. The first priority is to decontaminate open wounds. The second priority is to attend to facial orifices, followed by decontamination of intact skin. Efforts should be made to ensure that the material being decontaminated is not being transferred to previously decontaminated areas. Ensure that the patient is medically stable prior to commencing decontamination procedures.

Once the patient is medically stable, contamination concerns can be addressed. Universal standard precautions and proper patient handling techniques are usually effective protective precautions for health care personnel. If the patient is medically stable, the use of additional PPE can be implemented, if necessary.

The patient should be surveyed cursorily upon entry into the health care facility. This first simple survey will inform personnel of the presence or absence of contamination and, in the case of its presence, its general location and magnitude. This information may help inform staff of potential issues, e.g. contamination in the breathing zone or upper chest may indicate the potential for an inhalation intake. Once patient clothing has been removed, a detailed survey should be performed to identify areas of contamination. The patient will be protected from contamination transfer during the removal of contaminated clothes. The removed clothing should be retained for radioanalysis to determine the contaminating radioisotope. Excreta samples should be collected for bioassay to verify the presence or absence of potential internal dose issues.

Usually, the easiest decontamination technique is the best. It is often convenient to think of radiological contamination as equivalent to routine dirt, oil, grease, etc. that has some radioactive atoms interspersed within the material. Tepid water and soap are excellent decontaminating agents for intact skin. When decontaminating intact skin, care should be taken to avoid abrading the skin surface, thus creating a potential intake route.

Wound decontamination is typically carried out by irrigating the affected area with a sterile saline solution. The area around the wound should be superficially decontaminated, waterproof drapes placed around the wound, and runoff routed to a collection container (Fig. 7). Ensure that prior to each post-decontamination survey, the potentially contaminated drapes are removed to avoid any confusion with the location of residual contamination. Each decontamination attempt should be properly documented.

FIG. 7. Wound decontamination procedure and wound dressing of the staff and patient [7].

It is generally recommended that each area be decontaminated separately using the easiest method resulting in the least runoff. Showering the whole body when contamination is found only on the shoulder may not be the recommended decontamination method given its potential to spread the contamination to other portions of the body.

6.2. POPULATION

MPs supporting the response to nuclear or radiological emergencies may be called upon to help inform decision makers of information pertinent to the protection of the public. Emergency management and public health officials should use plume models or other predictions of deposition associated with a release of radioactive material in conjunction with information about the present conditions to make protective recommendations, for example, sheltering in place, evacuation, selection of appropriate public sheltering or community reception facilities.

In the case of potential population exposure to a sealed source (no release of contamination), the MP may be called upon to develop isodose curves that can be used to predict dose rates at various distances from the source. This information can be used in combination with personnel location information to help estimate doses to members of the public who may have been near the source. This information can be used, along with any medical signs and symptoms (clinical dose estimation), as well as other dose reconstruction of scenarios, biological dosimetry (analysing radiation induced changes at cellular level such as chromosomal anomalies) and others. A multidisciplinary approach is required in order to integrate this information.

It may also be necessary to collect excreta for radioanalysis to assess internal doses for a long period of time, even though this is not necessarily considered to be early dose magnitude estimation, but a more definitive dose assignment. This information may be used to determine whether medical treatment for internal contamination is necessary, to assess the efficacy of the treatment and to decide whether treatment can be terminated. Plans will address this need, especially for situations where a large number of people may be internally contaminated.

Plans should also include contingencies for the external decontamination of large numbers of individuals. While the underlying philosophy of not spreading contamination to non-contaminated areas will be followed, exceptions may need to be made in order to respond to the demands of the incident.

In summary, rapid dose estimation should inform, not decide, the medical management of victims of radiation incidents. Definitive dose assignment should occur at a later time. Until then, it is essential that health care providers and radiation protection professionals maintain an open line of communication. As new information becomes available, dose estimates and the resulting medical planning may be adjusted accordingly. Because of the unknowns associated with the circumstances of many radiation accidents, and the fact that radiation injuries and/or illness may progress over a protracted period of time, internal dose calculations may change based on continuing analysis of excreta results.

7. DEFINITIVE DOSE ASSESSMENT AND FOLLOW-UP

For definitive assessment and long term treatment decisions, it is essential that physicians, MPs and other professionals employ a multidisciplinary approach to provide medical support, dose estimations, an updated registry of individuals, medical follow-up and psychological support [20].

7.1. ROLE OF THE MEDICAL PHYSICISTS IN DOSE ASSESSMENT AND FOLLOW-UP

The MP should use the available information to help with early dose magnitude estimations (Section 5) and support the definitive dose assessment of exposed individuals. The MP can also assist in obtaining relevant information from individuals during early phases of the emergency, so that the information can be used in subsequent dose assessments. Furthermore, the MP, with suitable training, may assist local or national health authorities (as appropriate) in performing dose assessment for members of the public and identifying exposed individuals who are candidates for long term medical follow-up.

7.2. KEY CONSIDERATIONS

(a) It is important to collect key exposure histories shortly after exposure has occurred. Any later and individuals will rely more on their memory regarding where they were, at what time and for how long. The uncertainties regarding exposure parameters thus increase.
(b) Even with complete exposure histories collected from exposed individuals, there are uncertainties associated with radiation dose assessments, and it is important to acknowledge those uncertainties and, if possible, provide quantitative estimates of them
(c) For assigning doses to members of the public, it is best if a scientific advisory group reviews and endorses the dose assessment methodology before the labour intensive task of quantitative dose assessment is performed.
(d) The criteria for determining who will receive long term medical follow-up will aim to detect radiation induced cancers at an early stage, thereby enabling more effective treatment. These criteria will be based on current knowledge of the risks of radiation induced health effects [4, 8].
(e) Radiation dose is an important parameter in assessing eligibility for long term medical follow-up. However, the decision to include individuals in long term follow-up procedures may take into account social, scientific or economic factors; ultimately, the decision would be made by health authorities in consultation with stakeholders. The MP's contribution is to help provide accurate estimates of radiation doses and advise on possible or expected health outcomes.

7.3. DEFINITIVE DOSE ASSESSMENT

Definitive dose assessment for patients involved in nuclear or radiological emergencies refines the early dose estimations and provides more complete information to help guide the patient's medical management. A number of methodologies may be used to assess external and internal doses for patients, and these depend on their availability and appropriateness for the exposure situation. For example, cytogenetic biodosimetry is the gold standard for assessing external doses in cases of whole body irradiation. For internal doses, the bioassay analysis of excreta (urine or faeces, as appropriate for a specific radionuclide), and/or possibly whole body counting, could also provide reliable information on dose assessments.

The methodology proposed, adapted from Ref. [8], is the following:

(a) Confirm that evaluation of the following observable parameters was carried out in the field:
    - Specific circumstances of the exposure;
    - Skin and clothing contamination;
    - Dosimeter readings;
    - Thyroid monitoring (if applicable).

(b) Use the recommendations of the field RA or incident commander (on-scene controller) for further actions. If the evaluation was not carried out, conduct the evaluation (based on the information available) and take appropriate actions.
(c) For patients suspected of being at risk of developing deterministic effects, the RBE weighted absorbed dose of external exposure, and the committed RBE weighted absorbed dose of internal exposure, delivered over time Δ in the organ or tissue of concern, is then estimated using Eqs (2)–(7) below.
(d) The results of the dose assessment are evaluated and the worksheet F1 in Appendix III completed [8].
(e) Worksheet F1 is provided to medical personnel (the physician responsible for treatment or the public health officials responsible for registry) so that it can be compared with the generic dose criteria in Table 2 [4] for further action..

7.3.1. Internal exposure

$$AD_T^{\mathrm{Int}}(\Delta) = AD_T^{\mathrm{Inh}}(\Delta) + AD_T^{\mathrm{Ing}}(\Delta) \quad (2)$$

where

$AD_{\mathrm{T}}^{\mathrm{Int}}(\Delta)$ is the committed RBE weighted absorbed dose of internal exposure;
$AD_{\mathrm{T}}^{\mathrm{Inh}}(\Delta)$ is the inhalation committed RBE weighted absorbed dose;
$AD_{\mathrm{T}}^{\mathrm{Ing}}(\Delta)$ is the ingestion committed RBE weighted absorbed dose;

and Δ is the duration of the time period for estimating committed RBE weighted absorbed doses after an intake of radioactive material.

7.3.2. External exposure

In many cases, the RBE weighted absorbed dose in organ or tissue, *T,* from external exposure, $AD_{\mathrm{T}}^{\mathrm{Ext}}$, may be superseded by $AD_{\mathrm{Torso}}^{\mathrm{Ext}}$, the RBE weighted absorbed dose from external exposure averaged over the torso of the human body. Its value may be determined from the results of individual monitoring using Eq. (3) for exposure to photons and Eq. (4) for exposure to neutrons.

$$AD_{\mathrm{Torso}}^{\mathrm{Ext}} = \theta^{\gamma} \times E_{\mathrm{Ext}}^{\gamma} = \theta^{\gamma} \times H_P^{\gamma}(10) \quad (3)$$

$$AD_{\mathrm{Torso}}^{\mathrm{Ext}} = \theta^{n} \times E_{\mathrm{Ext}}^{n} = \theta^{\gamma} \times H_P^{n}(10) \quad (4)$$

where

$E_{\mathrm{Ext}}^{\gamma}$ is the effective dose from external exposure to photons;
$E_{\mathrm{Ext}}^{\mathrm{n}}$ is the effective dose from external exposure to neutrons;

$H_P^{\gamma}(10)$ is the personal dose equivalent of external exposure to photons;
$H_P^{n}(10)$ is the personal dose equivalent of external exposure to neutrons;

θ^{γ} is the ratio of the relative RBE for severe deterministic effects to the average quality factor for photons, which is 1.

and θ^{n} is the ratio of the relative RBE for severe deterministic effects to the average quality factor for neutrons, which is 3.

The personal dose equivalents of external exposure are measured from dosimeter readings by individual dosimeters (applicable to occupational exposed workers that might be involved in a radiological accident);

7.3.3. Combined exposure

In the case of combined internal and external exposure, an index of RBE weighted absorbed doses for intake of radioactive material and for external exposure should be used for decision making.

$$I_T = \frac{AD_{\mathrm{T}}^{\mathrm{Ext}}}{AD_{\mathrm{T,\,Threshold}}} + \left(\frac{AD_{\mathrm{T}}^{\mathrm{Int}}(\Delta)}{AD(\Delta)_{\mathrm{T,\,Threshold}}}\right)^2 \qquad (5)$$

where

$AD(\Delta)_{\mathrm{T,\,Threshold}}$ is the threshold committed RBE weighted absorbed dose for developing severe deterministic effects due to internal exposure of an organ or tissue, *T*, as listed in Table 2 [4];

and $AD_{\mathrm{T,\,Threshold}}$ is the threshold committed RBE weighted absorbed dose for developing severe deterministic effects due to external exposure of an organ or tissue, *T*, as listed in Table 2 [4];

If $I_T > 1$, the probability of developing severe deterministic effects of combined exposure of an organ or tissue, *T*, is to be treated as significant.

7.3.4. Total effective dose

For all affected people, the total effective dose, E_{Tot}, can be estimated using the Eq. (6).

$$E_{\mathrm{Tot}} = E_{\mathrm{Ext}} + E_{\mathrm{Inh}}(\tau) + E_{\mathrm{Ing}}(\tau) \qquad (6)$$

where

E_{Tot} is the total effective dose;
E_{Ext} is the effective dose from external exposure;
$E_{\mathrm{Inh}}(\tau)$ is the committed effective dose from inhalation;

and $\mathrm{E}_{\mathrm{Ing}}(\tau)$ is the committed effective dose from ingestion.

The effective dose from external exposure is estimated using available information. If data from personal dosimeters are available, Eq. (7) is used.

$$E_{Ext} = H_P(10) \qquad (7)$$

where $H_P(10)$ is the individual dose equivalent as measured by individual dosimeter readings.

7.4. CONSIDERATIONS RELATED TO THE PUBLIC

In addition to individuals brought to hospitals for treatment, there may be a large number of people who do not need hospitalization or immediate medical treatment, but who have been exposed to radiation. Local or national health and emergency management authorities should use environmental measurement and radiation dose modelling to estimate radiation doses for the potentially exposed population. If necessary, they will then issue protective action recommendations, such as evacuation or sheltering in place, to protect the public. Afterwards, local or national health authorities may perform a more definitive assessment of doses for members of the public based on environmental measurements, geographical location and exposure histories, to determine whether any members of the public will need long term medical follow-up. MPs may be asked to provide assistance in this process.

7.5. RECOVERY PHASE AND FOLLOW-UP ACTIONS

The long term medical follow-up of affected people involves performing regular medical examinations with the purpose of enabling early diagnosis and effective treatment of radiation induced health effects, such as cancer. The MP may be asked to assist in this process and provide scientific and technical support. The following information is provided mainly for general awareness of the process [8]:

(a) For guidance on criteria for epidemiological follow-up of affected people, see Table 2 [4].
(b) A registry of persons to be tracked and to receive long term medical follow-up will be established.
(c) A minimum initial data set for persons suspected of being exposed to significant levels of irradiation or contamination will contain:
    (i) Basic demographic details;
    (ii) Their exact position/location at the moment of the emergency (or their best recollection thereof);
    (iii) Results of the survey for contamination (both internal and external);
    (iv) Personal dosimetry results, if available;
    (v) Histories of any injuries — conventional/radiation induced/combined;
    (vi) Details of any treatment given.
(d) People included in the registry should be informed — in plain language — of their risk level and of the purpose of the registry.

Medical services are provided as needed for early recognition and treatment of the stochastic consequences to the affected people in the registry. See also Appendix III.

8. EFFECTIVE COMMUNICATION

Communication is key during any emergency. Timely and iterative messages that are clear and accurate will improve the effectiveness of the response during a crisis. It is also important to mention that preparedness and education of the population before a crisis provide a good basis for communication during the response period. There is need for MPs to enhance their communications skills, so that they can contribute to the timely dissemination of relevant information and contribute, all with the response team, in managing individuals and professionals involved in nuclear or radiological emergencies. The following is a brief summary of actions. Nevertheless, further training in this area is necessary in order to collaborate with communication teams.

The overall objective of effective crisis communication is:

(a) To mitigate the effects of a nuclear or radiological emergency on people and the environment;

(b) To ensure that communication with involved individuals consists of messages that include the appropriate level of urgency related to crisis situations. The desired outcome is to provide the public and professionals with information that will help them make the best decision possible, taking into account the likely existence of challenging constraints during nuclear or radiological emergencies;
(c) To ensure that communication helps to mitigate psychological impacts while providing all individuals with the relevant information they need at the given moment.

8.1. ROLE OF THE MEDICAL PHYSICISTS IN COMMUNICATION DURING NUCLEAR OR RADIOLOGICAL EMERGENCIES

MPs can act as part of a larger mechanism providing technical input as 'subject matter experts' in accordance with the communication strategy of each organization, and eventually be in contact with the professionals responsible for communication.

It is important to mention that the MP will not be solely responsible for the crisis communication role but may play an important role, collaborating in the development and/or adjustment of messages to the population, other professionals or to authorities. In any case it is relevant that MPs know the key element of communication aspects that may be applied to any emergency.

8.2. KEY CONSIDERATIONS

8.2.1. Communication aspects

(a) The early messages and actions of an emergency response will have a significant impact on how people respond, their perception of risk and their attitude to the emergency response organization. These foundational moments can establish the organization as a trusted source of information, and are critical to the overall emergency response and its ability to manage public behaviour. Communication is a key tool at this stage.
(b) Information needs to be provided so that it will be clearly understood by people in distress, who will be showing signs of irritability, anxiety, fear, withdrawal and emotional numbness. This means that all involved professionals will demonstrate the requisite respect and empathy for those involved in the situation at hand, providing information in clear, short, easy to understand terms.
(c) It is very important to build trust during communication during a nuclear or radiological emergency. The more trust people feel towards the staff and agencies managing an emergency, the less afraid they will be and the more able they will be to take actions to protect themselves [33]. Trust can be established by being accurate, transparent and timely with messages.
(d) During an emergency, the overall approach to communication should always be proactive [34]. The different groups need to be kept constantly informed, even if just to tell them that no more news is available at the given time.
(e) Messages that will be communicated in all public information products should be consistent in the language and formats used by all the interested parties. Reinforcement of the coordination of all parties should be encouraged.

8.2.2. Psychosocial aspects of nuclear or radiological emergencies

(a) Risk perception plays an important role in determining the reaction of the population to the assumed or expected consequences of any emergency, even if they have not yet occurred. However, psychosocial effects are often underestimated or even ignored.

(b) Mental health needs to be a high priority of consequence management, because the number of affected individuals experiencing psychosocial effects could easily overwhelm health systems [35].
(c) Understanding emotional factors contributing to risk perception is basic to any risk communication programme [33].
(d) Having a basic knowledge of psychosocial effects will also increase the MP's understanding of how to communicate with affected patients in an effective way.

Useful and actionable advice on psychological first aid may be found in the World Health Organization publication Psychological First Aid: Guide for Field Workers [36].

8.3. ADDRESSING INFORMATION TO DIFFERENT AUDIENCES

During nuclear or radiological emergencies, different audiences have unique concerns requiring unique messages [32]. MPs should be prepared to provide technical inputs for the creation of appropriate messages addressed to different target audiences.

8.3.1. Identification of target audiences

The target audiences usually encountered in a hospital environment are the following:

(a) Affected members of the public (patients) at the hospital. The messages for this target audience should be based on realistic estimations of dose and the potential effects of radiation exposure to individuals or populations. Messages should not create unnecessary anxiety.
(b) Relatives (next of kin) of affected individuals. These individuals will be very concerned about the well-being of their relatives. For this reason, they may be difficult to manage and will need information and reassurance.
(c) Professionals involved in the response (e.g. emergency medical management physicians and nurses):
    - These professionals will need advice on estimations of the dose received by patients, so that physicians may decide on and implement appropriate treatments.
    - They will also need reassurance that it is safe to handle specific, possibly contaminated patients.
(d) Hospital based staff not directly involved in the response to nuclear or radiological emergencies. A significant portion of the hospital staff will be involved at their full capacity with the emergency at hand. Staff will need advice on how to perform their duties that have been modified due to the nuclear or radiological emergency. It is expected that staff members will be concerned about their own radiation protection. In this case, MPs will need to advise their concerned colleagues on effective methods of handling contaminated or irradiated patients (or waste) while keeping their personal dose and contamination levels as low as possible. For example, MPs would need to give clear indications to:
    - Nurses, physicians and other clinical personnel on methods of keeping their personal dose as low as possible while caring for contaminated patients;
    - Non-clinical staff (e.g. cleaners, maintenance) on methods and dose related to the handling of radioactive/contaminated waste or other material.
(e) Interested parties at different levels who may be part of the response mechanism (e.g. hospital managers). MPs may need to explain various issues related to radiation and its effects to interested parties. MPs will need to provide quantified, actionable information in a simple way. Sometimes decisions may have to be made in situations of uncertainty.

(f) Reporters and the press. In the event that the MP is asked by the hospital authorities to speak to the media, the MP should provide information in a concise and trustworthy manner, sticking to the facts without creating unnecessary panic and anxiety. MPs will avoid providing personal opinions and judgements that are not supported by facts.

8.3.2. Identification of key issues

For every target audience, it is important to identify and prioritize issues that need to be addressed. This is a critical step before the creation of the actual messages.

8.3.3. Developing appropriate messages

It must be emphasized that the messages addressed to each target audience should be commensurate with their knowledge and understanding of radiation and its effects. MPs are encouraged to assess the average level of understanding and knowledge of each group. They should work with communication specialists to develop these messages. Note that even people with a high level of understanding will be under stress and will have more difficulty comprehending than usual. They, too, will need simple, actionable messages [37].

Key messages should be concise points that can be easily remembered by the public and integrated into multiple information products and formats. They should include action steps. For example, in the case of a lost radiation source, the message may read as follows: 'A powerful radiation source can cause serious injury if handled or even simply touched; if you see a metal object with the radiation warning symbol, stay away from it and call the authorities.'

8.3.4. Transmitting a message

Some key elements in transmitting a message to the population, other professionals and/or authorities for effective communication in the context of any emergency can be summarized as follows:

(a) Be first. Responding quickly is important because crises are time sensitive.
(b) Be right. Being right builds credibility. The information to be provided has to include:
  - What is known;
  - What is not known;
  - What is being done to fill gaps.

(c) Be credible. Honesty and transparency help maintain credibility.
(d) Be empathetic. People who suffer need their suffering to be acknowledged. Empathy builds trust.
(e) Be proactive. Action calms anxiety by keeping the individual occupied with meaningful and useful actions, while promoting their sense of control after a frightening incident.
(f) Be respectful. Respect promotes cooperation [37].

9. SPECIFICATIONS FOR A GRAB-AND-GO KIT TO RESPOND TO NUCLEAR OR RADIOLOGICAL EMERGENCIES

Medical physicists responding to nuclear or radiological emergencies will need equipment and tools for radiation protection and for performing their work on the scene. For this reason, it is deemed essential that a hospital maintain a specific 'grab-and-go' kit for the responding MPs. This kit is meant to be preserved in operational condition. Processes ensuring the kit's operational condition are to be in place at the hospital.

Tables 8–13 provide a list of basic proposed contents for the grab-and-go kit. It should be noted that, depending on local expected operational conditions, the kit may need to contain items that are not included in this list. Ideally the team will include more than one person. However, the quantities given in the list of items are for one person and should be multiplied by the number of people on the team.

Detectors and dosimeters need to be calibrated. A mechanism needs to be in place to ensure the routine replacement of items as needed (batteries, individual dosimeters, etc.).

The quantities included are just a reference that can be considered depending on the number of responders and need to be adapted to local resources and the results of self-assessment.

9.1. DOSIMETERS

TABLE 8. TYPES OF DOSIMETERS NEEDED FOR RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

Item	Description	Quantity
Electronic personal dosimeters (EPDs)[a]	● Range: — Dose: 1 μSv to 1 Sv — Dose rate: 1 μSv/h to 1 Sv/h ● Audible, visual and tactile (vibration) alarms for accumulated dose or dose rate; ● Lightweight and rugged; ● Standard batteries; ● Quick response time.	2
Additional batteries for dosimeters[b]	Standard batteries that may be found on the market (Standard batteries for the EPDs that may be found on the market (AA, AAA or other))	16
Individual dosimetry badges (the same as the ones used in the hospital)[b]	Thermoluminescent dosimeter (TLD), optically stimulated luminescence (OSL), film or EPD based	1

[a] Pocket ionization chambers may be used as alternatives. The MP needs to be aware of limitations in its cumulative dose and dose range capabilities.

[b] These will need to be replaced periodically.

9.2. INSTRUMENTATION, SURVEY METERS AND RADIATION DETECTORS

TABLE 9. TYPES OF INSTRUMENTATION NEEDED FOR RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

Item	Description	Quantity
Survey meter for ambient dose detection (beta and gamma radiation detection)	Appropriate survey meter (ionization chamber, Geiger–Müller or scintillation detector) with a window allowing the detection of beta radiation: ● Range: — Dose rate: 0.1 μSv/h to 1 Sv/h	2

	● Audible and visual alarms for high dose rate; ● Lightweight and rugged; ● Standard batteries; ● Quick response time.	
Contamination meter with probe for surface contamination detection *A survey meter for alpha particle detection may be required in some cases*	Geiger–Müller probe will be less accurate above 100 000 counts/min. Typical background: 27–575 counts/min	2
Wipe test kits	Wipes for sampling removable contamination need to be available	20
Critical spare parts for the measurement equipment	Cables, extra probes (if any), batteries	2 sets
Plastic bags	Transparent plastic bags of an adequate size to contain the instruments or probes that need to be protected from contamination	50

Note: Some of the equipment described requires special prior training. Proposed quantities of consumables are based on the assumption that replenishment is possible within 48 h.

9.3. BASIC PROTECTIVE EQUIPMENT

TABLE 10. BASIC TYPES OF PROTECTIVE EQUIPMENT NEEDED FOR RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

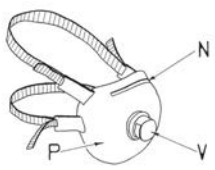
Item	Description	Quantity
Protective suits	Non-ventilated, non-pressurized, impermeable suits. Such suits protect from surface contamination (solid and liquid) as well as weak airborne contamination (aerosols and gases). Disposable The disposal suits may be used for most conditions in the controlled areas of a hospital. **Additional suits (for example, ten) need to be included in the kit in case of failure or for other members of the team**	2
Gloves	Lightweight, disposable polyethylene or latex gloves	25 pairs
Shoe covers or overshoes	Disposable, single size, foot shaped plastic bags with elastic openings: ● Personal footwear may be worn underneath; ● Offers protection from minor spills.	25 pairs

Surgical caps (or bonnets)		25
Sealing tape	Preferably waterproof	25 m or more
Lightweight, plastic face shields		25

Note: It is important to be aware that other hazards may be present (e.g. chemical, electrical) and to ask for more information from on-site safety officer(s). The on-site safety officer will determine PPE requirements, taking into account other possible hazards. Proposed quantities of consumables are based on the assumption that replenishment is possible within 48 h.

9.4. PROTECTIVE EQUIPMENT TO CONSIDER

TABLE 11. TYPES OF INSTRUMENTATION NEEDED FOR RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

Item	Description	Quantity
High specification masks for use by the responding MP (in case of deployment to a relatively highly contaminated area) *Use of such equipment requires specialized training*	Full face mask respirators made of moulded rubber or plastic and covering the entire face. Held in place with adjustable head harnesses [38]. 	1
Filters for the high specification masks *The on-site safety officer will advise on the changing of filters.*	Cartridges of appropriate filters suitable for radiological protection Care has to be taken so that appropriate filters for any contaminants that can be encountered (particulate/charcoal filters) are available for use with masks.	4 sets
Disposable masks to be handed out to protect people at the scene from radionuclide inhalation	Filtering face piece (FFP) respirators. The FFP3 class provides adequate protection for either low risk or limited risk areas or for short exposures within the specified limits [38]. 	20

Note: Be aware that other hazards may be present (e.g. chemical, electrical) and ask for more information from an on-site safety officer. The on-site safety officer will determine personal protective requirements taking into account other possible hazards. Proposed quantities of consumables are based on the assumption that replenishment is possible within 48 h. Some of the equipment described requires special prior training.

9.5. DATA SHEETS, FORMS AND EQUIPMENT INSTRUCTION MANUALS

TABLE 12. TYPES OF INFORMATIONAL MATERIAL AND FORMS NEEDED FOR RESPONSE TO NUCLEAR OR RADIOLOGICAL EMERGENCIES

Item	Description	Quantity
Data sheet with recommended OIL values for skin contamination [13]	See Appendix III.1	1
Worksheet for on-scene contamination monitoring [8]	See Appendix III.2	50 copies +1 electronic version
Worksheet record for patient radiological survey [8]	See Appendix III.3	50 copies +1 electronic version
Worksheet or record for patient dose assessment [8]	See Appendix III.4	50 copies +1 electronic version
Inventory checklist	A list of all items contained in the grab-and-go kit.	1
Instruction manuals and flashcards for measurement equipment	Laminated pages containing quick-start and use information for equipment. Assume that the user does not necessarily remember how to use equipment in the kit. *Flash cards have to be concise and easy to read in conditions of emergency.*	1 for each device
Emergency phone numbers, radio frequencies (in case the use of radios is necessary)	To be compiled according to local infrastructure and emergency plans	1
Organizational diagrams (to coordinate with other responders)	To be compiled according to local infrastructure and emergency plans	1
Electronic device (Note PC, Smartphone, Tablet)	To input the data on electronic version of the worksheets	1

9.6. OTHER TOOLS

TABLE 13. MISCELLANEOUS TOOLS AND ITEMS NEEDED FOR THE RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

Item	Quantity
Scissors	1
Pliers	1
Cutter or knife	1
Flashlight (hand-wound)	1
Pens or pencils	2
Notebook	1
Plastic foil	1 roll
Cellular phone with charger	1
A copy of this publication	1+1 electronic version
Electronic device (note PC, Smartphone, Tablet)	1

10. SYLLABUS FOR TRAINING MEDICAL PHYSICISTS FOR NUCLEAR OR RADIOLOGICAL EMERGENCIES

Although CQMPs working in hospitals have in-depth knowledge of radiation dosimetry, including dose reconstruction and dose measurements, they are usually not involved in nuclear or radiological emergencies. However, in a few instances where MPs have been involved in nuclear or radiological emergencies, it appeared that many lacked specific knowledge and some skills that are required in such situations. This absence of specific knowledge and skills is probably due to the fact that most current medical physics curricula do not include a specific module on this topic.

This section provides guidance on important aspects that must be considered in curricula for the EPR training of MPs for nuclear or radiological emergencies. This training should also impart a good understanding of the potential complementary roles of MPs to prepare them to contribute effectively to the response to nuclear or radiological emergencies. The potential role in preparedness also considers that MPs can actively contribute in the training of other health care professionals in responding to nuclear or radiological emergencies.

To facilitate the understanding and systematic approach required for the learning process, the educational aspects and specific matters for an EPR training programme for MPs can be organized in modules as follows:

- Module 1: Introduction;
- Module 2: Nuclear and Radiological Emergencies;
- Module 3: Radiation Measurements and Instrumentation;
- Module 4: Dose Assessment and Dose Reconstruction;
- Module 5: Monitoring and Decontamination of People and Waste Management at the Scene and Reception Centres;

— Module 6: Monitoring and Decontamination of People and Waste Management at the Hospital;
— Module 7: Biological Effects of Radiation: Cell and Tissue Effects and Stochastic Effects;
— Module 8: Protection Strategies for the Public;
— Module 9: Protection Strategies for Workers;
— Module 10: Medical Management;
— Module 11: Psychosocial Effects and Impacts on Mental Health;
— Module 12: Effective Risk Communication;
— Module 13: Education and Training in Nuclear or Radiological Emergencies (Theory and Practice and Training).

A standard organization of contents has been proposed for each module, including its: objective; prerequisites; learning outcomes; core knowledge and competencies; and, additionally, a complementary reading list with publications that will serve as a basis for students and lecturers. The modules are presented as described in Tables 14–26.

Module 1 provides an overview of the role of MPs and an understanding potential preparedness and response activities according to international standards (Table 14).

TABLE 14. MODULE 1: INTRODUCTION

Objective	To introduce the participants to the role of the MP in order to respond properly in nuclear or radiological emergencies, and to orient them to the topics and prepare them for the course. This module will also introduce participants to the framework of disaster medicine.
Prerequisites	Admission to the training workshop; necessary prior learning as required by each module.
Learning outcomes	• Awareness of the general concept and medical physics aspects of preparedness and response to nuclear or radiological emergencies; • Understanding of the role of the MP within an emergency response plan and the requirements to act efficiently and effectively; • Knowledge of the various types and planning categories of nuclear or radiological emergencies; • Familiarity with the relevant IAEA Safety Standards and Safety Guides.
Core knowledge and competencies	• Nuclear and radiological emergencies; • Radiation measurement and instrumentation; • Dose assessment and reconstruction; • Monitoring, decontamination and waste management; • Biological effects of radiation; • Protection strategies for public and workers; • Medical management and psychosocial effects of nuclear or radiological emergencies; • Risk communication; • Training in nuclear or radiological emergencies; • The role of the MP in response teams.

Reading list

- EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).
- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).
- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-G-2.1, IAEA, Vienna (2007).
- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Postgraduate Medical Physics Academic Programmes, Training Course Series No. 56, IAEA, Vienna (2013).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists, IAEA Human Health Series No. 25, IAEA, Vienna (2013).
- INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Generic Procedures for Medical Response during a Nuclear or Radiological Emergency, IAEA-EPR Medical, IAEA, Vienna (2005).
- INTERNATIONAL LABOUR OFFICE, International Standard Classification of Occupations, ISCO-08, ILO, Geneva (2008).
- INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, Policy Statements No.1, The Medial Physicist: Role and Responsibilities, IOMP, York (2010).
- INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, Policy Statements No.2, Basic Requirements for Education and Training of Medical Physicists, IOMP, York (2010).
- INTERNATIONAL ORGANIZATION FOR MEDICAL PHYSICS, Policy Statements No.3, Predictions of induced cancers and cancer deaths in a population of patients exposed to low doses (<100 mSv) of ionizing radiation during medical imaging procedures, IOMP, York (2013).

Module 2 focuses on preparedness and response to nuclear or radiological emergencies, key definitions and operational criteria that need to be considered (Table 15). This module is of major importance because it provides the basis for the modules that follow and the understanding of actions during the response.

TABLE 15. MODULE 2: NUCLEAR AND RADIOLOGICAL EMERGENCIES

Objective	To provide an overview of nuclear or radiological emergencies, introducing the participant to the emergency response framework.
Prerequisites	Awareness of national emergency response plans.
Module content	• An overview of nuclear and radiological emergencies; • Knowledge of the types of emergencies and emergency planning categories; • General aspects of preparedness and response to nuclear or radiological emergencies; • Applicability of the IAEA safety standards to specific situations; • An understanding of the possible roles of the MP, considering the characteristics of various types of nuclear or radiological emergencies.
Core knowledge and competencies	• The fundamentals of nuclear and radiological emergencies; • A framework for emergency response criteria; • A breakdown of the types of emergency; • Emergency planning categories; • Information on areas and zones; • The basic responsibilities for EPR; • The goals of EPR; • Interventional levels and operational criteria; • Information on past emergencies; • Identification of response teams and communication between different groups.
Reading list	• EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014). • FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015). • FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS OFFICE FOR THE

COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, Arrangements for Preparedness for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GS-G-2.1, IAEA, Vienna (2007).

- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).
- INTERNATIONAL ATOMIC ENERGY AGENCY, The Radiological Accident in Goiânia, IAEA, Vienna (1988).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Lessons Learned from Accidental Exposures in Radiotherapy, Safety Reports Series No. 17, IAEA, Vienna (2000).

Module 3 considers theoretical and practical aspects related to radiation measurements and instrumentation (Table 16).

TABLE 16. MODULE 3: RADIATION MEASUREMENTS AND INSTRUMENTATION

Objective	Provide an overview of the main types of monitoring instrumentation used in nuclear and radiological emergencies, and provides an opportunity for participants to acquire the knowledge and skills to measure radiation levels with the proper instrumentation. It also serves as a guide for the creation and use of a medical physics kit.
Prerequisites	Knowledge of fundamental radiation physics (e.g. interaction with matter, radiation detection, quality control, calibration, uncertainties).
Learning outcomes	• Perform a variety of radiation measurements with a range of instruments (including dose rate surveys); • Perform functional and calibration checks; • Discuss the difficulties in alpha, beta, low energy photon and neutron measurements; • Select appropriate monitoring instrumentation for nuclear or radiological emergencies; • Understand the physical limitations and uncertainties of dose measurements; • Keep an inventory of available equipment in the hospital; • Understand how to create, maintain and use an emergency grab-and-go kit for responding to nuclear or radiological emergencies; • Understand the performance of radiation measurement instruments and their use during nuclear or radiological emergencies.
Core knowledge and competencies	• Radiation measurement systems specific to and suitable for nuclear or radiological emergencies (e.g. detectors, contamination monitors, in vivo monitoring, personal dosimeters, gamma spectroscopy, portal monitors); • Use of nuclear medicine instrumentation in nuclear or radiological emergencies; • Quality control of measurement (e.g. calibration, physical limitations, uncertainty); • Surface contamination measurements; • Ambient dose rate measurements with survey meter; • Activity measurements with NaI or Ge spectrometers; • In vivo activity measurements with whole body counter; • Keeping an inventory of available equipment and resources in the hospital;

		• Conduct basic dose rate surveys; • Basic measurements of contaminated foodstuffs and water.
Reading list		• BURGESS, P.H., Guidance on the Choice, Use and Maintenance of Hand-Held Radiation Monitoring Equipment, National Radiological Protection Board, Rep. NRPB R326, NRPB, Chilton, United Kingdom (2001). • BURGESS P., et al, Practical Radiation Monitoring, Measurement, Good Practice Guide No. 30, National Physical Laboratory, Teddington, United Kingdom (2014). • KNOLL,G.F., Radiation Detection and Measurement, 4th edn, Wiley, New York (2011). • INTERNATIONAL ATOMIC ENERGY AGENCY, Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP Public Protective Actions 2013, IAEA, Vienna (2013). • INTERNATIONAL ATOMIC ENERGY AGENCY, Individual Monitoring, Practical Radiation Technical Manual No. IAEA-PRTM-2 (Rev. 1), IAEA, Vienna (2004). • INTERNATIONAL ATOMIC ENERGY AGENCY, Measurement of Radionuclides in Food and the Environment: A Guidebook, Technical Reports Series No. 295, IAEA, Vienna (1989). • INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Intervention Levels for Reactor Emergencies and Methodology for their Derivation, EPR-NPP-OILs 2017, IAEA, Vienna (2017). • INTERNATIONAL ATOMIC ENERGY AGENCY, Workplace Monitoring for Radiation and Contamination. Practical Radiation Technical Manual No1 (Rev. 1), IAEA, Vienna (2004).

Module 4 considers the basics of dose assessment and reconstruction, which are important during preparedness and response to nuclear or radiological emergencies (Table 17).

TABLE 17. MODULE 4: DOSE ASSESSMENT AND DOSE RECONSTRUCTION

Objective	Understand the methods and tools that may be used for dose assessment and reconstruction as relevant to medical management in nuclear or radiological emergencies.
Prerequisites	• Knowledge of ICRU report 60 and ICRP report 103; • Basic knowledge of internal dose calculation models; • Understanding of the radiation measurement quantities and units necessary to perform dose assessment and reconstruction.
Learning outcomes	• Know how quantities are applied to estimations of radiation dose. • Know how model limitations and uncertainties may affect dose estimations. • Estimate radiation dose when data may be incomplete. • Use the appropriate ICRP models for internal and external dose estimation. • Estimate external and internal dose from direct, as well as indirect, ionizing radiation, if necessary. • Estimate dose from intake of contaminated food and water. • Advise on personal dosimetry in emergency situations. • Assess the basic environmental impact of nuclear or radiological emergencies and how they contribute to dose. • Recognize basic nuclides dispersed in the environment during nuclear or radiological emergencies.

	• Understand the role of the MP in the assessment and reconstruction of radiation dose during nuclear or radiological emergencies.
Core knowledge and competencies	• Physical, protection and operational quantities (ambient dose equivalent, personal dose equivalent); • Quantities used for external radiation dose; • Quantities used for internal radiation dose (committed equivalent dose and committed effective dose); • Models used to estimate radiation dose from intake of radionuclides (lung model, gastrointestinal tract model, systemic models for retention and excretion); • Phantoms for radiation dose estimation; • Use of dose assessments and reconstructed doses; • Concept and limitation of collective dose; • Basic nuclides dispersed in the environment during nuclear or radiological emergencies; • Internationally agreed intervention levels for water and food.
Reading list	• EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014). • INTERNATIONAL ATOMIC ENERGY AGENCY, Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP Public Protective Actions 2013, IAEA, Vienna (2013). • INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Radiation Protection Monitoring Instruments, Safety Reports Series No. 16, IAEA, Vienna (2000). • INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Intervention Levels for Reactor Emergencies and Methodology for their Derivation, EPR-NPP-OILs 2017, IAEA, Vienna (2017). • INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Fundamental Quantities and Units for Ionizing Radiation, Report 60, ICRU, Bethesda, MD (1998). • INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Quantities and Units in Radiation Protection Dosimetry, ICRU Report 51, ICRU, Bethesda (1993). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 1, Publication 56, Pergamon Press, Oxford (1990). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations, Publication 109, Elsevier, Amsterdam (2009). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Compendium of Dose Coefficients based on ICRP Publication 60, Publication 119, Elsevier, Oxford (2012). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Conversion Coefficients for Radiological Protection

	Quantities for External Radiation Exposures, Publication 116, Elsevier, Oxford (2010). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Conversion Coefficients for Use in Radiological Protection against External Radiation, ICRP Publication 74, Pergamon Press, Oxford (1996). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Human Respiratory Tract Model for Radiological Protection, Publication 66, Pergamon Press, Oxford (1994). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, “Quantities used in radiological protection”, The 2007 Recommendations of the International Commission on Radiological Protection, Publication 103, Elsevier, Oxford (2007) Annex B.

Module 5 contains information related to the role of the MP, mainly at reception centres and possibly, under specified circumstances, at the scene (Table 18).

TABLE 18. MODULE 5: MONITORING AND DECONTAMINATION OF PEOPLE AND WASTE MANAGEMENT AT THE SCENE AND RECEPTION CENTRES

Objective	• Acquire knowledge about reception centres; • Identify the roles and responsibilities of MPs in a reception centre.
Prerequisites	Participants must revise the content of previous modules, in particular ‘Radiation Measurements and Instrumentation’ (Module 3).
Learning outcomes	• Design a reception centre; • Develop monitoring procedures based on the scale of the event and resources available; • Establish segregated radiation zones; • Take a leading role in setting up a reception centre (e.g. operational planning, staffing, layout design, arrangements to prevent contamination of the facility and communication with the members of the team); • Recognize criteria for the decontamination of people in a nuclear or radiological emergency; • Generate appropriate records of the monitoring and decontamination of individuals; • Provide radiation protection training of staff assigned to the reception centre; • Use equipment for the detection and quantification of possible external contamination of people in a nuclear or radiological emergency (handheld monitors, automatic hand and foot monitors, portal monitors); • Establish appropriate mechanisms of waste management in the reception centre; • Understand the role of the MP in the monitoring and decontamination of patients and waste management at the reception centre during nuclear or radiological emergencies
Core knowledge and competencies	• Design and establishment of a reception centre. • Fundamentals of radiation monitoring and decontamination procedures. National, regional and local nuclear or radiological emergency preparedness. Management of radioactive waste and associated radiation protection. • Training of staff in radiation protection.
Reading list	• INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Monitoring in a Nuclear or Radiological Emergency, IAEA-TECDOC-1092, IAEA, Vienna (1999).

- INTERNATIONAL ATOMIC ENERGY AGENCY, Medical Management of Persons Internally Contaminated with Radionuclides in a Nuclear or Radiological Emergency, EPR-Internal contamination-2018, IAEA, Vienna (2018).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Medical Preparedness and Response for a Nuclear or Radiological Emergency Training Materials, EPR-Medical/T, IAEA, Vienna (2014) Lectures 18, 23, 24, 26.
- INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Generic Procedures for Medical Response during a Nuclear or Radiological Emergency, IAEA-EPR Medical, IAEA, Vienna (2005).
- OHBA, T., et al., A strategy for a rapid radiological screening survey in large scale radiation accidents: A lesson from an individual survey after the Fukushima Daiichi nuclear power plant accidents, Health Phys. 107 1 (2014) 10–17.
- ROJAS-PALMA, C., et al., TMT Handbook. Triage, Monitoring, and Treatment of People Exposed to Ionising Radiation Following a Malevolent Act, SCK CEN, Norwegian Radiation Protection Authority, Health Protection Agency, Radiation and Nuclear Safety Authority, World Health Organization, Enviros Consulting Ltd., Central Laboratory for Radiological Protection. (2009).

Module 6 follows the same principles as the previous chapter, but applied to a hospital, considering such aspects as the external decontamination of people, waste management and acute health effects after an exposure to ionizing radiation (Table 19).

TABLE 19. MODULE 6: MONITORING AND DECONTAMINATION OF PEOPLE AND WASTE MANAGEMENT AT THE HOSPITAL

Objective	Focus on the unique issues pertaining to monitoring and decontamination in hospitals.
Prerequisites	• Radiation Measurements and Instrumentation (Module 3); • Monitoring and Decontamination of People and Waste Management at the Scene and Reception Centres (Module 5).
Learning outcomes	• Localize a radiation source, identify the radionuclide(s) and quantify the activity; • Describe situations in which life-threatening injuries take precedence over decontamination and monitoring; • Wound decontamination (shrapnel removal, debridement); • Understand the role of the MP in the monitoring and decontamination of patients and waste management within the hospital environment during nuclear or radiological emergencies.
Core knowledge and competencies	• Choice of appropriate instrumentation and techniques for localization, identification and quantification of radiation sources. • Strategies for decontamination of wounds. • Proper management of incidents to prioritize life-threatening injuries against decontamination and monitoring.

Reading list	• INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Assessment and Response during a Radiological Emergency, IAEA-TECDOC-1162, IAEA, Vienna (2000). • INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Monitoring in a Nuclear or Radiological Emergency, IAEA-TECDOC-1092, IAEA, Vienna (1999).

Module 7 describes the biological effects at the cellular level, as well as the deterministic and stochastic effects of ionizing radiation (Table 20).

TABLE 20. MODULE 7: BIOLOGICAL EFFECTS OF RADIATION: CELL AND TISSUE EFFECTS AND STOCHASTIC EFFECTS

Objective	• Understand the processes of carcinogenesis and genetic radiation effects and their influencing factors; • Understand the effects of ionizing radiation on cells and tissues and their medical consequences; • Characterize biological effects with respect to the relevant dose assessment (including biological dose indicators), dose response and risk models; • Acknowledge factors impacting the quality and quantity of these effects.
Prerequisites	• Basic understanding of anatomy and physiology; • Basic understanding of epidemiological methodology and its limitations; • Knowledge of biology related to carcinogenesis; • Basic knowledge of the effects of radiation on biological systems at the cellular, tissue, organ and whole organism levels.
Learning outcomes	• Describe the methodology for assessing probability of occurrence of stochastic and cell, tissue, organ and whole body effects; • Discuss requirements regarding exposure data selection and quality; • Discuss biological dose indicators; • Discuss dose response and risk models and explain dose response analyses; • Understand tissue tolerance and relevant influencing factors; • Interpret epidemiological data; • Understand the role of the MP in the assessment of probability and severity of biological effects of radiation.
Core knowledge and competencies	• Quantities and units (absorbed, equivalent dose). • The transformation of physical interaction to biological effects. • DNA damage and biological consequences. • Multi-step carcinogenesis theory, initiating and promoting factors. • Tumour incidence and mortality. • Cell survival and influencing factors (intrinsic radiosensitivity, cell cycle effects, radiation quality, dose rate and fractionation, overall exposure time, oxygenation), modes of cell death. • Dose calculations (linear quadratic (LQ) model, equieffective doses delivered in X Gy fractions (EQDx)). • Retrospective biological dose indicators (electron spin resonance (ESR), gene expression, cytogenetics (dicentrics, FISH, PCC), micronuclei, comet assay). • General pathogenesis of early, late and consequential late tissue effects, including latent times and typical examples. • Atypical tissue effects (e.g. eye lens, gonads, embryo/fetus).

- Radiation syndromes (cerebrovascular, gastrointestinal, mucocutaneous, haematopoietic) and relevant dose indicators (early clinical symptoms, lymphocytes, hair follicles, spermatogenesis).
- The impact of dose inhomogeneities (within organs, partial versus total body exposure).
- Dose–effect relationship, tolerance doses and risk models.
- Tissue weighting factors and effective dose.
- Factors influencing risk (including exposure conditions, e.g. dose rate, radiation quality, age at exposure, sex, genetic factors, lifestyle related factors, exposed organ) including examples.
- Factors influencing tissue effects (intrinsic radiosensitivity, recovery, repopulation, redistribution).
- Genetic radiation effects and consequences, with relevant examples.

Reading list

- BENTZEN, S.M., et al., Bioeffect modeling and equi-effective dose concepts in radiation oncology: Terminology, quantities and units, Radiother. Oncol.; **105** (2012) 266–268.
- DÖRR, W., SCHMIDT, M., “Normal tissue radiobiology”, Comprehensive Biomedical Physics, Vol. 7, Elsevier, Amsterdam (2014) Chapter 7.05.
- HALL, E.J., GIACCIA, A.J., Radiobiology for the Radiologist, 7th edn, Lippincott Williams and Wilkins, Baltimore (2012).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Cytogenetic Dosimetry: Applications in Preparedness for and Response to Radiation Emergencies, EPR-Biodosimetry 2011, IAEA, Vienna (2011).
- INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Biology: A Handbook for Teachers and Students, Training Course Series No. 42, IAEA, Vienna (2010).
- INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, ICRP Statement on Tissue Reactions/Early and Late Effects of Radiation in Normal Tissues and Organs: Threshold Doses for Tissue Reactions in a Radiation Protection Context, Publication 118, Elsevier, Oxford (2012).
- INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, The 2007 Recommendations of the International Commission on Radiological Protection, Publication 103, Elsevier, Oxford (2007).
- JOINER, M., VAN DER KOGEL, A., Basic Clinical Radiobiology, 4th edn, Hodder Education, London (2009).
- OZASA, K., et al., Studies of the mortality of atomic bomb survivors, 1950–2003: An overview of cancer and noncancer diseases, Radiat. Res. **177** 3 (2012) 229–243.
- SHRIEVE, D.C., LOEFFLER, J.S., Human Radiation Injury, 1st edn, Lippincott Williams and Wilkins, Baltimore (2011).
- UNITED NATIONS, “Levels and effects of radiation exposure due to the nuclear accident after the 2011 Great East-Japan Earthquake and Tsunami” Sources, Effects and Risks of Ionizing Radiation, (Report to the General Assembly), Vol. I, , , Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), UN, New York (2014) Annex A.
- UNITED NATIONS, “Non-targeted and delayed effects of exposure to ionizing radiation”, Sources, Effects and Risks of Ionizing Radiation (Report to the General Assembly), Vol. II,: UN, New York (2006) Annex C.

Module 8 provides information about protection strategies based on a study of past experience (Table 21).

TABLE 21. MODULE 8: PROTECTION STRATEGIES FOR THE PUBLIC

Objective	Provide an understanding of the basic concepts, strategies and measures for protecting the public in the event of nuclear or radiological emergencies.
Prerequisites	Module 1–7
Learning outcomes	• Understand and discuss the basic strategies for the prevention of deterministic and stochastic events; • Describe methods to reduce exposure to the public using protective actions in response to nuclear or radiological emergencies; • Recognize the situations when sheltering, evacuation and relocation are recommended; • Recognize when the response may include actions to reduce inadvertent ingestions, decontamination of individuals and prevention of ingestion of potentially contaminated food, milk or water, or reduce uptake of radioactive iodine; • Describe the strategy to prevent the spread of contamination through embargo and quarantine of food crops and livestock; • Describe OILs; • Recognize the cases where iodine thyroid blocking is required; • Describe the role of the MP in the radiation protection of contaminated or overexposed members of the public.
Core knowledge and competencies	• Preventive actions to avoid the spread of contamination; • Methods to reduce public exposure, including countermeasures; • Pathways of exposure through food, milk and water; • Techniques and strategies to reasonably reduce public exposure and dose during an emergency.
Reading list	• EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014). • FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011). • INTERNATIONAL ATOMIC ENERGY AGENCY, Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP Public Protective Actions 2013, IAEA, Vienna (2013). • INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Generic Procedures for Medical Response During a Nuclear or Radiological Emergency, EPR-Medical 2005, IAEA, Vienna (2005).INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report

	on Preparedness and Response for a Nuclear or Radiological Emergency in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2013). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations, Publication 109, Elsevier, Amsterdam (2009).

Module 9 discusses protection strategies for emergency workers before, during and after a nuclear or radiological emergency and the role of the MP (Table 22).

TABLE 22. MODULE 9: PROTECTION STRATEGIES FOR WORKERS

Objective	Provide an understanding of the basic concepts, strategies and measures for protecting workers in nuclear or radiological emergencies.
Prerequisites	Preparedness and Response for a Nuclear or Radiological Emergency in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant [7].
Learning outcomes	• Explain the components of the ALARA (as low as reasonably achievable) concept and how it is implemented in an emergency situation; • Describe the concept of universal precautions and its value in reducing worker contamination; • Discuss radiation protection measures for workers that may be used in emergency response; • Prepare dose estimates of workers with elevated radiation levels in the environment and of radioactive contamination of people and buildings; • Explain knowledge of the arrangements for controlling, and guidance values for restricting, the exposure of emergency workers; • Describe the role of the MP in the radiation protection of contaminated or overexposed workers.
Core knowledge and competencies	• Universal precautions; • ALARA principles and implementation in an emergency; • Calculating individual dose estimates from radiation measurements in the environment; • Techniques and strategies to reasonably minimize practical worker dose during an emergency; • Estimating measurable quantities (ambient dose equivalent, personal dose equivalent).
Reading list	• EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014). • FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use

	in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011). • INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Report on Preparedness and Response for a Nuclear or Radiological Emergency in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, IAEA, Vienna (2013). • INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Generic Procedures for Medical Response During a Nuclear or Radiological Emergency, IAEA-EPR Medical, IAEA, Vienna (2005). • INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations, Publication 109, Elsevier, Amsterdam (2009). • INTERNATIONAL ATOMIC ENERGY AGENCY, Manual for First Responders to a Radiological Emergency, EPR-First Responders 2006, IAEA, Vienna (2006).

Module 10 considers the medical management of individuals involved in nuclear or radiological emergencies. Also discussed are the radiological aspects of individuals under life-threating and stable conditions, explanations based on case studies and measures adopted, as well as the role of the MP in the health care team (Table 23).

TABLE 23. MODULE 10: MEDICAL MANAGEMENT

Objective	Provide general knowledge about medical response to nuclear or radiological emergencies (incident site, reception centre/emergency ward, advanced care).
Prerequisites	Modules 4–6
Learning outcomes	• Describe the basic concepts of radiation emergency medicine; • Understand the physician's perspective in triage and treatment; • Describe the role of the MP in the evaluation and follow-up of contaminated or overexposed patients.
Core knowledge and competencies	• Levels of response to an incident (on-site, reception centre, hospital); • Medical management of acute radiation syndrome, cutaneous radiation syndrome (local radiation injury), and contaminated patients (internal and external); • Clinical cases (Chile, France, Goiânia, Morocco and Peru accidents — clinical accidents, specifically in radiotherapy); • Role of the MP in the treatment of overexposed or contaminated patients; • Chelating agents: Their use and limitations; • Basic concepts of radiation emergency medicine; • Clinical flow of treatment and management for emergency cases; • International cooperation and networking for assistance in nuclear or radiological emergencies.
Reading list	• INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Generic Procedures for Medical Response during a Nuclear or Radiological Emergency, IAEA-EPR Medical, IAEA, Vienna (2005). • INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Publications on Accident Reports, https://www.iaea.org/topics/accident-reports

	• INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Medical Preparedness and Response to a Nuclear or Radiological Emergency, EPR-MEDICAL/T 2014, IAEA, Vienna (2014). • ROJAS-PALMA, C., et al., TMT Handbook. Triage, Monitoring, and Treatment of people exposed to ionising radiation following a malevolent act. SCK CEN, Norwegian Radiation Protection Authority, Health Protection Agency, Radiation and Nuclear Safety Authority, World Health Organization, Enviros Consulting Ltd., Central Laboratory for Radiological Protection. (2009). • TAZRART, A., BERARD, P., LEITERER, A., MENETRIER, F., Decontamination of radionuclides from skin: An overview, Health Phys. 105 2 (2013) 201–207.

The psychosocial consequences of nuclear or radiological emergencies are one of the most important non-radiological consequences to the population exposed, workers and the non-exposed population. Even if the MP does not provide the counselling, it is important to understand the impact of these consequences, and the actions that can be taken. Module 11 focuses on impacts on mental health (Table 24).

TABLE 24. MODULE 11: PSYCHOLOGICAL EFFECTS AND IMPACTS ON MENTAL HEALTH

Objective	Provide MPs with an awareness of the importance of sociopsychological stress arising from nuclear or radiological emergencies.
Prerequisites	None
Learning outcomes	• Describe some major psychological effects resulting from nuclear or radiological emergencies; • Discuss the concept of risk perception; • Understand the possible role of the MP in tackling psychological effects, and the impact of nuclear or radiological emergencies on the mental health of contaminated or overexposed patients, workers and residents.
Core knowledge and competencies	• Risk perception for individuals, the population and groups of interest. • Psychosociological effects of nuclear or radiological emergencies. Type and level of mental stress, depending on the situations of evacuation (e.g. temporary housing, voluntary evacuation). • Short and long term psychological effects after the nuclear or radiological emergency (e.g. Fukushima Health Management Survey). • Mental health consequences for health care workers. • Social, cultural and economic consequences of nuclear or radiological emergencies.
Reading list	• BROMET, E.J., Mental health consequences of the Chernobyl disaster, J. Radiol. Prot. **32** 1 (2012) N71–N75. • SLOVIC, P., Informing and educating the public about risk, Risk Anal. **6** 4 (1986) 403–415. • THE CHERNOBYL FORUM, Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine, 2nd rev. edn, IAEA, Vienna (2006). • YABE, H., et al., Psychological distress after the Great East Japan Earthquake and Fukushima Daiichi Nuclear Power Plant accident: Results of a mental

health and lifestyle survey through the Fukushima Health Management Survey in FY2011 and FY2012, Fukushima J. Med. Sci. **60** 1 (2014) 57–67

The subject of Module 12, effective risk communication, is one of the most important actions in any emergency (Table 25). The role of the MP can be relevant in supporting these actions, providing a technical background to improve the effectiveness of communications.

TABLE 25. MODULE 12: EFFECTIVE RISK COMMUNICATION

Objective	Present an overview of effective risk and crisis communication in response to nuclear or radiological emergencies, and facilitate the acquisition of practical knowledge and skills for effective risk and crisis communication.
Prerequisites	Experience in interacting with health care professionals, such as medical doctors and nurses, and fundamental knowledge of radiation protection principles.
Learning outcomes	• Describe communication, with particular reference to risk and crisis communication; • Explain the principles and strategies of effective communication; • Discuss public perception of risk; • Adjust effective communication styles to different social and economic backgrounds and regulatory frameworks; • Describe the role of MPs in a multidisciplinary emergency response team; • Recognize the barriers to risk communication, radiation quantities and units, insufficient evidence of low dose risk assessment, and public perception of risks; • Understand the role of the MP in effective risk communication during nuclear or radiological emergencies.
Core knowledge and competencies	• The fundamental knowledge of risk communication; • The basic techniques of risk communication; • The 3Cs (consensus, care, crisis) of communication; • The principles of communicating risk to the public; • Various communication tools such as social media; • The role of risk communication as a component of risk analysis (the other components are risk management and risk assessment); • Interview strategies and guidelines.
Reading list	• AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY, A Primer on Health Risk Communication, ATSDR, Atlanta (1987). • CENTERS FOR DISEASE CONTROL AND PREVENTION, Crisis Emergency and Risk Communication, CDC, Atlanta (2012). • COVELLO, V.T., Risk communication, radiation, and radiological emergencies: strategies, tools and techniques, Health Phys. 101 5 (2011) 511–530. • ENVIRONMENTAL PROTECTION AGENCY, Communicating Radiation Risks: Crisis Communications for Emergency Responders, Rep. EPA 402-R-07-008, EPA, Washington, DC (2007). • INTERNATIONAL ATOMIC ENERGY AGENCY, Communication with the Public in a Nuclear or Radiological Emergency – Training Materials, EPR-Public Communications/T 2012, Training Materials, IAEA, Vienna (2012) CD-ROM.INTERNATIONAL ATOMIC ENERGY AGENCY, Manual

for First Responders to a Radiological Emergency, EPR-First Responders 2006, IAEA, Vienna (2006).
- RISK AND REGULATION ADVISORY COUNCIL, A Practical Guide to Public Risk Communication: The Five Essentials of Good Practice, RRAC, London (2009).
- ROPEIK, D., Risk communication: More than facts and feelings, IAEA Bull. 50 1 (2008) 58–60.
- SCOTLAND AND NORTHERN IRELAND FORUM FOR ENVIRONMENTAL RESEARCH, Communicating Understanding of Contaminated Land Risks, SNIFFER, Edinburgh (2010).
- WORKING GROUP ON PUBLIC COMMUNICATION OF NUCLEAR REGULATORY ORGANISATIONS, Nuclear Regulatory Organisations, the Internet and Social Media: The What, How and Why of Their Use as Communication Tools, OECD Publishing, Paris (2014).

The role of the MP in training health care professionals at different levels is significant, which has major impacts on preparedness for nuclear or radiological emergencies (Module 13; Table 26). Elements and theories on education have to be considered to develop this part of the syllabus.

TABLE 26. MODULE 13: EDUCATION AND TRAINING IN NUCLEAR OR RADIOLOGICAL EMERGENCIES (THEORY, PRACTICE AND TRAINING)

Objective	Introduce participants to professional education and training and the design of appropriate teaching and learning activities so that they may become effective trainers of MPs and other health professionals, with special relevance to the support response to nuclear and/or radiological emergencies.
Prerequisites	No prerequisites exist, but this module is related to all other modules (2–14).
Learning outcomes	• Understand the role of the MP as an educator and trainer, within the multidisciplinary emergency response team, who will prepare others to take on a support role during nuclear or radiological emergencies; • Apply the principles and strategies of effective education and training of adults (health care professionals) to roll out local workshops for support in nuclear or radiological emergencies; • Design education and training processes and curricula for health care professionals of different categories and levels; • Interpret the curriculum and adjust the content to meet the needs of the local environment; • Prepare and present teaching and learning activities in line with the principles of professional and adult education; • Adjust the style of presentation and the teaching and learning activities to suit the professional categories and levels of the learners; • Contribute to building a team of health care professionals to respond to nuclear or radiological emergencies through the presentation of appropriate workshops and seminars.

Core knowledge and competencies	• The fundamental principles of adult and professional education and continuing professional development; • The Science and Technology Studies (STS) approach to enhance professionalism and build competence; • The use of presentation skills and teaching and learning techniques for the further development of health care professionals; • The principles of teamwork and team building that can be applied to the design of teaching and learning activities; • Methods of assessment and testing for the development of professional competence.
Reading list	• AOKI, T., Rethinking curriculum and pedagogy, Kappa Delta Pi Rec. **35** 4 (1999) 180–186. • CHHEM, R.K., CLANCEY, G.K., Eds, Health in Disasters: A Science and Technology Studies Practicum for Medical Students and Healthcare Professionals, IAEA, Vienna (2014), https://humanhealth.iaea.org/HHW/Latest/Health_in _Disasters/Handbook_Health_in_Disasters.pdf. • INTERNATIONAL ATOMIC ENERGY AGENCY, Communication with the Public in a Nuclear or Radiological Emergency – Training Materials, EPR-Public Communications/T 2012, Training Materials, IAEA, Vienna (2012) CD-ROM. • NATIONAL SCIENCE TEACHERS ASSOCIATION, “Science/technology/society: A new effort for providing appropriate science for all”, What Research Says to the Science Teacher: The Science, Technology and Society Movement (YAGER, R., Ed.), Vol. 7, National Science Teachers Association, Washington DC (1993) 3–7.

Appendix I
COMPLEMENTARY INFORMATION TO SECTION 5

I.1. SAMPLE HOSPITAL ENTRANCE SET-UP

Figure 8 presents a sample set-up for hospital reception areas for emergencies resulting in several casualties or mass casualties [8].

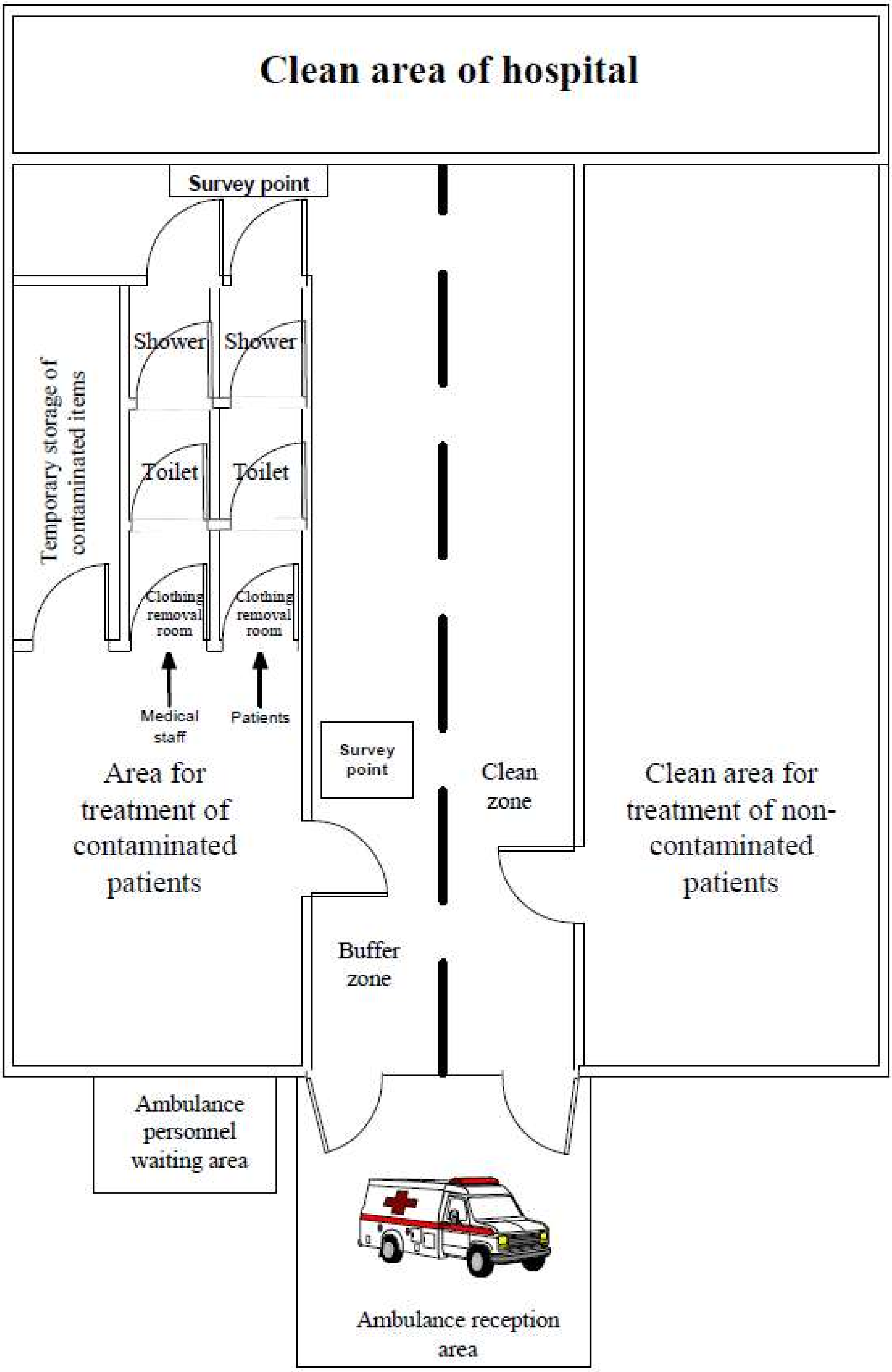


FIG. 8. An example of a hospital entrance set-up (reproduced from Ref. [8]).

I.2. SAMPLE TAG AND RECEIPT FOR CONTAMINATED ITEMS

Contaminated items must be properly wrapped, labelled, and stored in such a manner as to constitute no hazard to personnel and to control spread of contamination [39]. Figures 9 and 10 show respectively a sample tag and a sample receipt for contaminated items.

CAUTION
CONTAMINATED ITEM(S)

Date: ______________________ Time: ______________

Name: ______________________________________
(Emergency worker or owner)

Address: ____________________________________

____

Telephone No.: ______________________

Item Description	Max. Radiation Levels on the Surface*	
	Radiation type	[cps]
1.		
2.		
3.		

Responsible Person's Name: ______________________
(Radiological Assessor)

Signature: ______________________
(Radiological Assessor)

* Note: For details see original measurement records kept by Radiological Assessor.

FIG. 9. Example of a tag for contaminated items (reproduced from Ref. [39]).

RECEIPT FOR
CONTAMINATED ITEM(S)

Date: ______________________________ Time: __________________

Location: ____

Name: ____
(Emergency worker or owner name)

Address: ____

____

Telephone No.: ____________________________

Item Description/Approximate Value

Item Description	**Value**
1.	
2.	
3.	

The item(s) described will be returned if decontamination is possible.

Signatures:

______________________________ (Radiological Assessor)

______________________________ (Owner/Emergency worker)

ALL CLAIMS FOR REIMBURSEMENT SHOULD BE MADE TO:

____

FIG. 10. Example of a receipt for contaminated items (reproduced from Ref. [39]).

Appendix II
COMPLEMENTARY INFORMATION TO SECTION 6

Figures 11–13 show examples of worksheets for a person involved in a nuclear or radiological emergency on the early radiation dose assessment [8]. The worksheets should be adapted to reflect conditions for which they will be applied.

II.1. REGISTRATION FORM FOR PERSONS INVOLVED IN AN EMERGENCY

To be completed by: First responder (Police)	**WORKSHEET C2** **REGISTRY FORM FOR PERSON INVOLVED IN EMERGENCY**	*No. ______*

Full Name: ____________________________ (First Responder) Date: __________

Provide copy to: ☐ Emergency Medical Responder ☐ Public Health Advisor Time: __________

Information about person involved in the emergency:

Full name:____

Date of birth:_____/_____/_____ (Day Month year) Age:__________ Sex: ☐ M ☐ F

ID type and number:____________________________________

Current local full address:______________________________

Telephone No___________________

Current permanent full address:__________________________

Telephone No___________________

Member of: ☐ Public ☐ Facility staff ☐ Emergency Services

Radiological survey done: ☐ Yes ☐ No

If YES, attach Worksheet C1 with results.

Decontamination done: ☐ Yes, to level:_______ [ ] Unit ☐ No

Distance from the emergency when it happened:_____________________

Time of beginning of exposure (if any):_______ Time of end of exposure:_______

Duration of exposure:_______________ Position of the person:_____________

Remarks: ____

____

____

Signature:_____________

FIG. 11. Example of a worksheet for registering a person involved in a nuclear or radiological emergency (reproduced from Ref. [8]).

II.2. MEDICAL INFORMATION FORM FOR PERSONS INVOLVED IN AN EMERGENCY

To be completed by: Hospital Emergency Department Response Team	**WORKSHEET D2** **MEDICAL INFORMATION FORM**	*Page 1 of 3* *No. ______*

Full Name: ______________________________ (team member) Date: ___________

Provide copy to: ☐ Emergency Medical Manager Time: ___________

☐ Medical Specialist of Appropriate Service (if necessary)

☐ Referral hospital (if necessary)

Identification of the patient:

Full name:____

Date of birth:______/______/______ (Day Month Year) Sex: ☐ M ☐ F

Current local full address:____

Current permanent full address:____________________________________

Member of: ☐ Public ☐ Personnel ☐ Emergency Workers

Identification of the exposure conditions:

Date of emergency: _____/_____/_____ (Day Month Year) Presumed time of emergency:___________

Time of beginning of exposure:_________ Time of end of exposure:_____________

Duration of exposure:________________ Position of the patient:_______________

Nature of patient's work:____

The patient had a dosimeter: ☐ Yes ☐ No Dosimeter No:____________________

Dosimeter readings:________________ Body location of dosimeter(s):_________

Respiratory protection: ☐ Yes ☐ No Protective clothing: ☐ Yes ☐ No

Contamination of clothes: ☐ Yes ☐ No ☐ Not checked

Medical findings:

Date of examination: _____/_____/_____

First symptoms:

Clinical state

Nausea: ☐ Yes ☐ No Time of appearance________Number_____ Duration______

Vomiting: ☐ Yes ☐ No Time of appearance________Number_____ Duration______

Wound: ☐ Yes ☐ No Trauma: ☐ Yes ☐ No Burn: ☐ Yes ☐ No

Weakness: ☐ Yes ☐ No Headache: ☐ Yes ☐ No

FIG. 12. Example of a worksheet for medical information (reproduced from Ref. [8]).

II.3. FORM FOR THE RESULTS OF DOSE ASSESSMENT OF PERSONS INVOLVED IN AN EMERGENCY

To be completed by: Health/Medical Physicist	**WORKSHEET F1** **RESULTS OF DOSE ASSESSMENT**	*No.* ______

Full Name: ________________________________ Date: ___________
(Health/Medical Physicist)

Provide copy to:
☐ Hospital Emergency Department Response Team
☐ Medical Specialist of Appropriate Service
☐ Public Health Officer

Identification of the patient:

Full name:____

Code: _______ Date of birth:______/______/______

Weight [kg]:___________ Height [cm]: _______

Sex: ☐ M ☐ F (Pregnant: ☐ Yes ☐ No)

Results of dose estimation:

Dose	**Effective dose, Sv**
External	
Internal	
Total	

Radiation weighted dose to thyroid: __________________________, Sv

Organ or tissue	**RBE-weighted absorbed dose, Gy-Eq**		
	External	**Internal to date** ___/___/___	**Index to date** ___/___/___
Lung			
Colon			
Red marrow			
Thyroid			

Recommendations: ____
____
____

Signature:______________________________

FIG. 13. Example of a worksheet for the results of dose assessment of a person involved in a nuclear or radiological emergency (reproduced from Ref. [8]).

Appendix III
COMPLEMENTARY INFORMATION TO SECTIONS 7 AND 9

Table 27 presents the recommended actions for OILs for skin contamination (OIL4) [13]. Figures 14 and 15 show the 'OIL charts' (a practical tool for using the OILs during the response to an emergency) for skin monitoring (OIL4γ and OIL4β) and thyroid monitoring (OIL8γ) [40]. Figures 16–18 show examples of worksheets for recording the result of contamination monitoring, radiological survey and dose assessment to respond to a nuclear or radiological emergency [8]. The worksheets should be adapted to reflect conditions for which they will be applied. Table 28 provides information on identifying individuals for medical follow-up.

III.1. RECOMMENDED ACTIONS FOR OPERATIONAL INTERVENTION LEVELS (OILs) FOR SKIN CONTAMINATION (OIL4) AND FOR DOSE RATE FROM THE THYROID (OIL8)

TABLE 27. RECOMMENDED ACTIONS FOR OILs FOR SKIN CONTAMINATION (OIL4)
(adapted from Ref. [13])

OIL value	Response action (as appropriate) if the OIL is exceeded
Gamma (γ) 1 μSv/h at 10 cm from the skin 1000 counts/s direct beta (β) skin contamination measurement[c] 50 counts/s direct alpha (α) skin contamination measurement[c]	Provide for skin decontamination[a] and reduce inadvertent ingestion[b]. Register and provide for a medical examination.

[a] If immediate decontamination is not practicable, advise evacuees to change their clothing and shower as soon as possible.
[b] Advise evacuees not to drink, eat or smoke and to keep their hands away from their mouths until their hands are washed.
[c] This is performed using good contamination monitoring practice.

OIL CHART FOR SKIN MONITORING (LWRs) - GAMMA	
CHECKLIST	**ATTENTION: Only use this OIL if the answer to all the following questions is 'yes'.**
	Has there been a release of radioactive material from an LWR or its spent fuel? ☐ Yes ☐ No
	Are you assessing the ambient dose equivalent rate from the bare skin of the hand and face? ☐ Yes ☐ No
PURPOSE WITHIN THE PROTECTION STRATEGY	To be used to identify individuals with enough radioactive material on the skin to warrant response actions (such as decontamination). Only the public being evacuated or relocated is expected to possibly have sufficient radioactive material on the skin to warrant response actions. However, for reassurance, $OIL4_{\gamma}$ may be used with other members of the public as well. **Monitoring of the skin will only be effective over the first few days.** After a few days, most of the radioactive material will have been removed from the skin by natural processes. Keep in mind that the risk to health from skin contamination is small, and therefore monitoring or decontamination of the skin does not warrant delaying or interfering with more important response actions (e.g. sheltering, evacuation, treatment of injured individuals or patients).
MONITORING TYPE	Ambient dose equivalent rate at 10 cm from the bare skin of the hand and face conducted in an area with a background of less than 0.5 μSv/h.
DEFAULT OIL VALUE	**$OIL4_{\gamma}$ = 1 μSv/h** above background.
RESPONSE ACTIONS FOR ALL THOSE THAT MAY BE MONITORED	**Within the first hours after beginning of the exposure (before monitoring is implemented):** ▪ The primary concern from radioactive material on the skin is from inadvertent ingestion of the material. Thus, a person can be protected by taking such simple and non-disruptive measures as: (a) washing the hands before drinking, eating, smoking or touching the face; (b) not letting children play on the ground; and (c) avoiding activities resulting in the creation of dust that could be ingested or inhaled. ▪ Instruct to change clothing and shower as soon as possible, if it can be done safely (e.g. do not change or shower in cold temperatures). ▪ Reassure those treating and/or transporting contaminated individuals that they can do so safely if they use universal precautions against infection (i.e. gloves, mask, etc.).
RESPONSE ACTIONS IF $OIL4_{\gamma}$ IS EXCEEDED	**Within the first days after the beginning of the exposure:** ▪ Register all those being monitored and record the monitoring result (if practical). ▪ Provide for additional decontamination (apart from the simple decontamination measures mentioned above) by means considered appropriate and safe. ▪ Monitor the thyroid by using $OIL8_{\gamma}$. ▪ Provide medical screening. ▪ Instruct to take iodine thyroid blocking agents (if not already taken and only within the first days after reactor shutdown) to reduce further uptake of radioiodine. WHO guidance needs to be followed in this regard [37]. **Within weeks after the beginning of the exposure:** ▪ Estimate the dose from all exposure pathways for those exceeding $OIL4_{\gamma}$ to determine if medical follow-up is warranted in accordance with the IAEA Safety Standards Series Nos. GSR Part 7 [1] and GSG-2 [2].
IF $OIL4_{\gamma}$ IS <u>NOT</u> EXCEEDED	Check $OIL8_{\gamma}$.
HEALTH HAZARD	Chart 2 in Section 7 of IAEA EPR-NPP Public Protective Actions (2013) [4] can be used to place the **health hazard in perspective** when communicating with decision makers and public information officers.

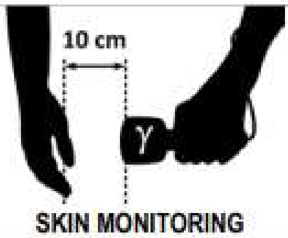


FIG. 14. Chart for skin monitoring (OIL4γ and OIL4β) (reproduced from Ref. [40]).

OIL CHART FOR THYROID MONITORING (LWRs)		
CHECKLIST	**ATTENTION: Only use this OIL if the answer to all the following questions is 'yes'.**	
	Has there been a release of radioactive material from an LWR or its spent fuel?	☐ Yes ☐ No
	Are you assessing the ambient dose equivalent rate measured in front of the thyroid in contact with the skin?	☐ Yes ☐ No
	Was the person decontaminated and the contaminated outer clothing removed before monitoring?	☐ Yes ☐ No
	Was the measurement taken in the first week after the possible intake of I-131?	☐ Yes ☐ No
	Did you use an instrument with an effective window area of ≤ 15 cm² and a response of ≥ 0.1 µSv/h per kBq of I-131 activity in the thyroid? Further details are given in Section 3.7.1.3.	☐ Yes ☐ No
PURPOSE WITHIN THE PROTECTION STRATEGY	To be used to identify individuals warranting registration and medical follow-up due to the intake of radioiodine, i.e. evacuated public or those that have ingested local produce, wild-grown products, milk from grazing animals, directly collected rainwater or local animals from an area exceeding OIL3$_\gamma$. For reassurance, OIL8$_\gamma$ may be used with other members of the public as well. The thyroid needs to be monitored within the first week to detect if an individual has inhaled or ingested sufficient radioiodine to warrant medical follow-up. Identifying the individuals is difficult later on. The early identification of those with an increased risk of developing thyroid cancer is paramount in their later medical follow-up and treatment. However, keep in mind that monitoring of the thyroid does not warrant delaying or interfering with other urgent response actions.	
MONITORING TYPE	Ambient dose equivalent rate in front of the thyroid: ▪ **In contact with the skin**; ▪ Measured **within the first week** after the intake of radioiodine; ▪ Conducted in an area with a background of less than 0.25 µSv/h; ▪ Measured after the person has been decontaminated and contaminated outer clothing has been removed; and ▪ Measured with an instrument with an effective window area of ≤ 15 cm² and a response of ≥ 0.1 µSv/h (ambient dose equivalent rate in front of the thyroid in contact with the skin) per kBq of I-131 activity in the thyroid (as described in Section 3.7.1.3.).	 **THYROID MONITORING**
DEFAULT OIL VALUE	**OIL8$_\gamma$ = 0.5 µSv/h** above background.	
RESPONSE ACTIONS FOR ALL THOSE TO BE MONITORED	**Before monitoring:** ▪ Instruct those to be monitored to reduce inadvertent ingestion by: (a) washing their hands before drinking, eating or smoking or touching the face; (b) not letting children play on the ground; and (c) avoiding activities resulting in the creation of dust that could be ingested or inhaled. ▪ Instruct those to be monitored to change clothing and shower as soon as possible, if it can be done safely (e.g. do not change or shower in cold temperatures). ▪ Reassure those treating and/or transporting contaminated individuals that they can do so safely if they use universal precautions against infection (gloves, mask, etc.).	
RESPONSE ACTIONS IF OIL8$_\gamma$ IS EXCEEDED	**Immediately following the monitoring:** ▪ Register all those monitored and record the monitoring result. ▪ Instruct to take iodine thyroid blocking agents to reduce further uptake of radioiodine (if not already taken and only within the first days after reactor shutdown). WHO guidance needs to be followed in this regard [37]. ▪ Provide medical screening. **Within weeks after the beginning of the exposure:** Estimate the dose from all exposure pathways for those exceeding OIL8$_\gamma$ to determine if a medical follow-up is warranted in accordance with the IAEA Safety Standards Series Nos. GSR Part 7 [1] and GSG-2 [2].	
IF OIL8$_\gamma$ IS NOT EXCEEDED	Register all those monitored and record the monitoring result (if practical). No further actions are necessary.	

FIG. 15. Reproduction of chart for thyroid monitoring (OIL8γ) (reproduced from Ref. [40]).

III.2. WORKSHEET FOR ON-SCENE CONTAMINATION MONITORING

To be completed by: Radiological Assessor	**WORKSHEET C1**	*No.* ______
	VICTIM CONTAMINATION CONTROL RECORD (ON-SCENE ASSESSMENT)	

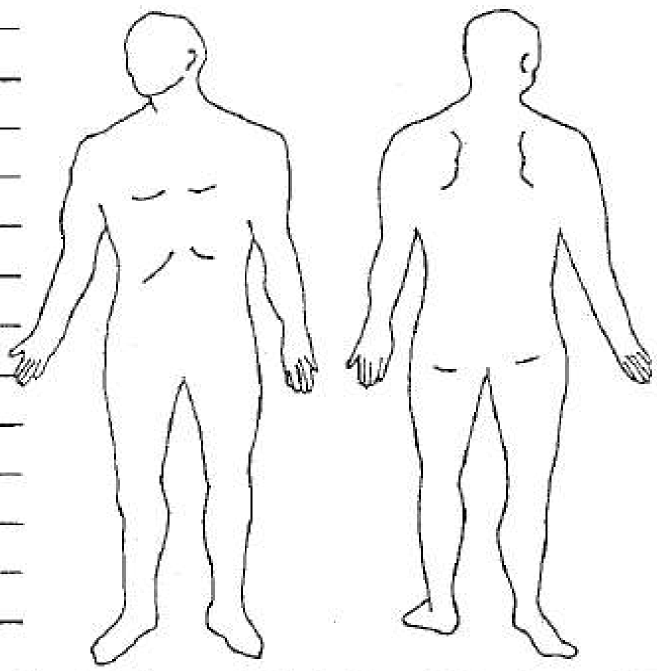
Surveyed by: ______________________________ Date: ___________
(Full name)

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. 16. Reproduction of a sample worksheet for radioactive contamination control of a person involved in a nuclear or radiological emergency (reproduced from Ref. [8]).

III.3. WORKSHEET FOR PATIENT RADIOLOGICAL SURVEY

To be completed by: Dosimetry Team	**WORKSHEET D1** **RECORD OF PATIENT RADIOLOGICAL SURVEY (AT HOSPITAL)**	*No.* ______

Surveyed by: ______________________________ Date: ___________
(Full name)

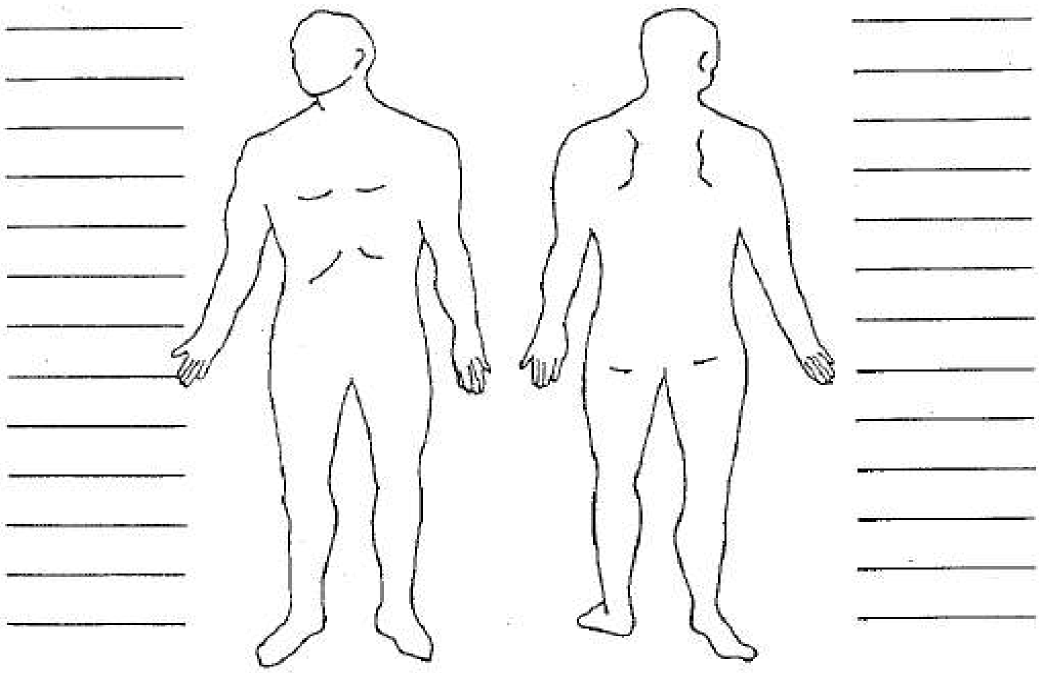
Provide to: ☐ Hospital Emergency Department Response Team
☐ Health/Medical Physicist Time: ___________

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: _____________ [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.

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. 17. Reproduction of a sample worksheet for a radioactive contamination survey of a person involved in a nuclear or radiological emergency (reproduced from Ref. [8]).

III.4. WORKSHEET OR RECORD FOR PATIENT DOSE ASSESSMENT

To be completed by: Health/Medical Physicist	**WORKSHEET F1** **RESULTS OF DOSE ASSESSMENT**	*No.* ______

Full Name: ______________________________ Date: ___________
(Health/Medical Physicist)

Provide copy to:
☐ Hospital Emergency Department Response Team
☐ Medical Specialist of Appropriate Service
☐ Public Health Officer

Identification of the patient:

Full name:____

Code: _______ Date of birth:_____/_____/_____

Weight [kg]:___________ Height [cm]: _______

Sex: ☐ M ☐ F (Pregnant: ☐ Yes ☐ No)

Results of dose estimation:

Dose	**Effective dose, Sv**
External	
Internal	
Total	

Radiation weighted dose to thyroid: ________________________, **Sv**

Organ or tissue	**RBE-weighted absorbed dose, Gy-Eq**		
	External	**Internal to date** ___/___/___	**Index to date** ___/___/___
Lung			
Colon			
Red marrow			
Thyroid			

Recommendations: ____
____
____

*Signature:*__________________________

FIG. 18. Reproduction of a sample worksheet for the results of dose assessments of a person involved in a nuclear or radiological emergency (reproduced from Ref. [8]).

III.5. MEDICAL FOLLOW-UP

TABLE 28. IDENTIFYING INDIVIDUALS FOR MEDICAL FOLLOW-UP
(adapted from Ref. [41])

Individuals	Comments
Those within the precautionary action zone (PAZ) and urgent protective action planning Zone (UPZ) during or following release Those in areas where OIL1 or OIL2 were exceeded	Need to provide information on their location and activities during the emergency. Also need to have skin and thyroid monitored.
Those with concentration of radioactive material on the skin exceeding OIL4	Skin contamination above OIL4 could indicate that the person has inhaled or inadvertently ingested enough radioactive material to warrant a medical follow-up.
Those with a dose rate from the thyroid exceeding OIL8	Monitoring of the thyroid and skin is necessary after 1 d and before 6 d following exposure.
Those who may have consumed contaminated food, milk or water with concentrations exceeding OIL7	No comments
Concerned pregnant women	All pregnant women within the PAZ and UPZ, who were in areas where OIL1 or OIL2 was exceeded, had their thyroid or skin monitored, or who have concerns, needs to be registered and told that: (a) the risk to their fetus is small, but it can only be assessed by an expert on the health effects of radiation exposure (not their local physician); and (b) that their risk will be evaluated, and an official will contact them to discuss the results and answer their questions.

In order to determine who needs to receive later medical follow-up, and to provide a basis for informed counselling of pregnant women and others, the doses to those categories of people listed in Table 28 need to be estimated.

The purpose of the OILs described is the following:

(a) OIL1, OIL2 and OIL3: Assessing ground deposition;
(b) OIL4: Assessing skin contamination;
(c) OIL7: Food, milk and water radionuclide concentrations;
(d) OIL8: Thyroid from radioactive iodine intake.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists, IAEA Human Health Series No. 25, IAEA, Vienna (2013).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Train the trainers workshop on medical physics support for nuclear or radiological emergencies, Atlanta, 2016.

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Pocket Guide for Medical Physicists Supporting Response to a Nuclear or Radiological Emergency, EPR-Pocket Guide for Medical Physicists 2020, IAEA, Vienna (2020).

[4] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL CIVIL AVIATION ORGANIZATION, INTERNATIONAL LABOUR ORGANIZATION, INTERNATIONAL MARITIME ORGANIZATION, INTERPOL, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, PREPARATORY COMMISSION FOR THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, UNITED NATIONS OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS, WORLD HEALTH ORGANIZATION, WORLD METEOROLOGICAL ORGANIZATION, Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSR Part 7, IAEA, Vienna (2015).

[5] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

[6] INTERNATIONAL ATOMIC ENERGY AGENCY, Manual for First Responders to a Radiological Emergency, EPR-First Responders 2006, IAEA, Vienna (2006).

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, Train the Trainers Workshop on Medical Physics Support for Nuclear or Radiological Emergencies (Proc. 1st Workshop Fukushima, 2015), IAEA, Vienna (2015), https://humanhealth.iaea.org/HHW/MedicalPhysics/TrainingEvents/FukushimaJune2015/index.html

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, WORLD HEALTH ORGANIZATION, Generic Procedures for Medical Response During a Nuclear or Radiological Emergency, EPR-Medical 2005, IAEA, Vienna (2005)

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Communication with the Public in a Nuclear or Radiological Emergency, EPR-Public Communications 2012, IAEA, Vienna (2012).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry, Safety Reports Series No. 34, IAEA, Vienna (2003).

[11] INTERNATIONAL ATOMIC ENERGY AGENCY, Dangerous Quantities of Radioactive Material (D-Values), EPR-D Values 2006, IAEA, Vienna (2006).

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Training for Radiation Emergency Preparedness and Response, First Response to a Radiological Emergency — Training Materials, EPR-First Responders/T 2009, IAEA, Vienna (2009).

[13] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR OFFICE, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, Criteria for Use in Preparedness and Response for a Nuclear or Radiological Emergency, IAEA Safety Standards Series No. GSG-2, IAEA, Vienna (2011).

[14] RADIATION EMERGENCY ASSISTANCE CENTER/TRAINING SITE, Early Internal and External Dose Magnitude Estimation, REAC/TS, Oak Ridge, TN (2015).

[15] SMITH, D.S., STABIN, M.G., Exposure rate constants and lead shielding values for over 1,100 radionuclides, Health Phys. **102** (2012) 271–291.

[16] MCGINNIS, R., Rad Pro Calculator (2006), http://www.radprocalculator.com

[17] ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE, BAT — Biodosimetry Assessment Tool version 1.06 (2013), https://www.usuhs.edu/afrri/biodosimetrytools

[18] UNITED STATES DEPARTMENT OF HEALTH AND HUMAN SERVICES, Guidance on Diagnosis and Treatment for Healthcare Providers, Dose Estimator for Exposure: 3 Biodosimetry Tools, HHS, Washington, DC (2017).

[19] INTERNATIONAL ATOMIC ENERGY AGENCY, Cytogenetic Dosimetry: Applications in Preparedness for and Response to Radiation Emergencies, EPR-Biodosimetry 2011, IAEA, Vienna (2011).

[20] INTERNATIONAL ATOMIC ENERGY AGENCY, Medical Management of Persons Internally Contaminated with Radionuclides in a Nuclear or Radiological Emergency, EPR-Internal Contamination-2018, IAEA, Vienna (2018)

[21] DAINIAK, N., WASELENKO, J.K., ARMITAGE, J.O., MacVITTIE, T.J., FARESE, A.M., The Hematologist and Radiation Casualties, ASH Education Program, Washington, DC (2003) 473–496.

[22] SUGARMAN, S.L., TOOHEY, R., GOANS, R., CHRISTENSEN, D., WILEY, A., Rapid internal dose magnitude estimation in emergency situations using annual limits on intake (ALI) comparisons, Health Phys. **98** (2010) 815–818.

[23] TOOHEY, R.E., BERTELLI, L., SUGARMAN, S.L., WILEY, A.L., CHRISTENSEN, D.M., Dose coefficients for intakes of radionuclides via contaminated wounds, Health Phys. **100** (2011) 508–514.

[24] TOOHEY, R.E., BERTELLI, L., SUGARMAN, S.L., WILEY, A.L., CHRISTENSEN, D.M., Dose Coefficients for Intakes of Radionuclides via Contaminated Wounds, Ver. 2, Aug 2014, Radiation Emergency Assistance Center/Training Site, Oak Ridge Institute for Science and Education, Oak Ridge, TN (2014).

[25] DELACROIX, D., GUERRE, J.-P., LEBLANC, P., HICKMAN, C., Radionuclide and radiation protection data handbook 1998, Radiat. Prot. Dosim. **76** (1998).

[26] JOHNSON, T.E., BIRKY, B.K., SHLEIEN, B. (Eds), Health Physics and Radiological Health, 4th edn, Lippincott Williams and Wilkins, Baltimore (2012).

[27] CENTERS FOR DISEASE CONTROL AND PREVENTION, Use of Radiation Detection, Measuring, and Imaging Instruments to Assess Internal Contamination from Intakes of Radionuclides, CDC, Atlanta, GA (2014), https://emergency.cdc.gov/radiation/clinicians/evaluation/

[28] RADIATION EMERGENCY ASSISTANCE CENTER/TRAINING SITE, The Medical Aspects of Radiation Incidents, REAC/TS, Oak Ridge, TN (2013).

[29] CENTER FOR RADIATION PROTECTION KNOWLEDGE, Rad Toolbox v 3.0.0, Oak Ridge National Laboratory, Oak Ridge, TN (2014), https://www.ornl.gov/crpk/software

[30] RADAR — the RAdiation Dose Assessment Resource (2001), http://www.doseinfo-radar.com/

[31] NATIONAL INSTITUTES FOR QUANTUM AND RADIOLOGICAL SCIENCE AND TECHNOLOGY, MONDAL3 Support System for Internal Dosimetry (2013), https://www.nirs.qst.go.jp/db/anzendb/RPD/mondal3.php

[32] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION., Compendium of Dose Coefficients Based on ICRP Publication 60, Publication 119, Elsevier, Oxford (2013).

[33] INTERNATIONAL ATOMIC ENERGY AGENCY, Communication with the Public in a Nuclear or Radiological Emergency – Training Materials, EPR-Public Communications/T 2012, IAEA, Vienna (2012), CD-ROM.

[34] INTERNATIONAL ATOMIC ENERGY AGENCY, Method for Developing a Communication Strategy and Plan for a Nuclear or Radiological Emergency, EPR-Public Communications Plan 2015, IAEA, Vienna (2015).

[35] NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS, Management of Terrorist Events Involving Radioactive Material, NCRP, Bethesda MD (2001).

[36] SNIDER, L., VAN OMMEREN, M., SCHAFER, A., Psychological First Aid: Guide for Field Workers, World Health Organization, Geneva (2011).

[37] CENTERS FOR DISEASE CONTROL AND PREVENTION, Crisis and Emergency Risk Communication, CDC, Atlanta (2012).

[38] INTERNATIONAL ATOMIC ENERGY AGENCY, Personal Protective Equipment, Practical Radiation Technical Manual No. 5. IAEA, Vienna (2004).

[39] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Procedures for Assessment and Response during a Radiological Emergency, IAEA-TECDOC-1162, IAEA, Vienna (2000).

[40] INTERNATIONAL ATOMIC ENERGY AGENCY, Operational Intervention Levels for Reactor Emergencies and Methodology for their Derivation, EPR-NPP-OILs 2017, IAEA, Vienna (2017).

[41] INTERNATIONAL ATOMIC ENERGY AGENCY, Actions to Protect the Public in an Emergency due to Severe Conditions at a Light Water Reactor, EPR-NPP Public Protective Actions, IAEA, Vienna (2013).

ABBREVIATIONS

AFRRI	Armed Forces Radiobiology Research Institute
ALARA	as low as reasonably achievable
BAT	Biodosimetry Assessment Tool
CDC	Centers for Disease Control and Prevention
CQMP	clinically qualified medical physicist
EPD	electronic personal dosimeter
EPR	emergency preparedness and response
FISH	fluorescence in situ hybridization
ICS	incident command system
MP	medical physicist
OIL	operational intervention level
OSL	optically stimulated luminescence
PCC	premature chromosome condensation
PPE	personal protective equipment
RA	radiological assessor
REAC/TS	Radiation Emergency Assistance Center/Training Site
RBE	relative biological effectiveness
TLD	thermoluminescent dosimeter

CONTRIBUTORS TO DRAFTING AND REVIEW

Akahane, K.	National Institutes for Quantum and Radiological Science and Technology, Japan
Akashi, M.	Ryugasaki Public Health Center, Japan
Ansari, A.	Centers for Disease Control and Prevention, United States of America
Berris, T.	International Atomic Energy Agency
Bowling, J.	Thompson Cancer Survival Center, United States of America
Fukuda, S.	National Institutes for Quantum and Radiological Science and Technology, Japan
Fukumura, A.	National Institutes for Quantum and Radiological Science and Technology, Japan
Gilley, D.	International Atomic Energy Agency
Herrera Reyes, E.D.	International Atomic Energy Agency
Isaksson, M.	University of Gothenburg, Sweden
Kim, E.	National Institutes for Quantum and Radiological Science and Technology, Japan
King, S.	Penn State Health Milton S. Hershey Medical Center, United States of America
Kraus, T.	Sandia National Laboratories, United States of America
Kumagai, A.	National Institutes for Quantum and Radiological Science and Technology, Japan
Kurihara, O.	National Institutes for Quantum and Radiological Science and Technology, Japan
Meghzifene, A.	International Atomic Energy Agency
Nüsslin, F.	Technical University of Munich, Germany
Ohtsuru, A.	Fukushima Medical University, Japan
Papp, C.	Comisión Nacional de Energía Atómica, Argentina
Siegel, V.	Centers for Disease Control and Prevention, United States of America
Sugarman, S.	Summit Exercises and Training, United States of America
Tamaki, T.	Fukushima Medical University, Japan
Vilar Welter, P.	International Atomic Energy Agency

IAEA
International Atomic Energy Agency

No. 26

ORDERING LOCALLY

IAEA priced publications may be purchased from the sources listed below or from major local booksellers.

Orders for unpriced publications should be made directly to the IAEA. The contact details are given at the end of this list.

NORTH AMERICA

Bernan / Rowman & Littlefield

15250 NBN Way, Blue Ridge Summit, PA 17214, USA
Telephone: +1 800 462 6420 • Fax: +1 800 338 4550
Email: orders@rowman.com • Web site: www.rowman.com/bernan

REST OF WORLD

Please contact your preferred local supplier, or our lead distributor:

Eurospan Group

Gray’s Inn House
127 Clerkenwell Road
London EC1R 5DB
United Kingdom

Trade orders and enquiries:

Telephone: +44 (0)176 760 4972 • Fax: +44 (0)176 760 1640
Email: eurospan@turpin-distribution.com

Individual orders:

www.eurospanbookstore.com/iaea

For further information:

Telephone: +44 (0)207 240 0856 • Fax: +44 (0)207 379 0609
Email: info@eurospangroup.com • Web site: www.eurospangroup.com

Orders for both priced and unpriced publications may be addressed directly to:

Marketing and Sales Unit
International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 or 22530 • Fax: +43 1 26007 22529
Email: sales.publications@iaea.org • Web site: www.iaea.org/publications

20-01403E

EPR-Medical Physicists

2020

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISSN 2518–685X