EPR-Pocket Guide for Medical Physicists

2020

EMERGENCY PREPAREDNESS AND RESPONSE

Pocket Guide for Medical Physicists Supporting Response to a Nuclear or Radiological Emergency

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POCKET GUIDE FOR MEDICAL PHYSICISTS SUPPORTING RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

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POCKET GUIDE FOR MEDICAL PHYSICISTS SUPPORTING RESPONSE TO A NUCLEAR OR RADIOLOGICAL EMERGENCY

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

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FOREWORD

The medical management of individuals involved in a nuclear or radiological emergency requires specially trained personnel. The lessons learned from previous radiation emergencies have demonstrated that the medical management of these individuals requires a multidisciplinary team of health care professionals, which is essential for an effective response.

In most hospitals, the clinical team includes medical physicists with special responsibility for the proper and safe application of ionizing radiation. Medical physicists have in-depth knowledge of radiation dosimetry, dose reconstruction and the dose assessment procedures performed daily. Thus, they constitute a unique group of professionals who can join medical teams and, with the appropriate training, provide appropriate support for emergency preparedness and response teams.

This guide includes basic information and references, presented in a user-friendly format, to assist specially trained medical physicists in supporting the response to a nuclear or radiological emergency. In addition to providing information on nuclear or radiological emergencies, this guide also describes the basic components of a response kit for medical physicists involved in responding to a nuclear or radiological emergency.

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

The IAEA acknowledges the endorsement of this publication 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.

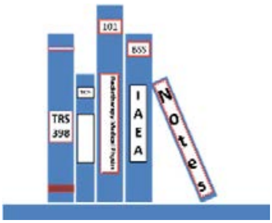
The IAEA officers responsible for this publication were E.D. Herrera Reyes of the Incident and Emergency Centre and T. Berris and A. Meghzifene of the Division of Human Health.

1. INTRODUCTION

This pocket guide:

Is a quick reference guide to be used by medical physicists (MPs) supporting the response to nuclear or radiological emergencies (hereinafter referred to as 'radiation emergencies'). It includes basic information and procedures and aims to help MPs contribute to the management of radiation emergencies in an efficient and coordinated manner.

Is a companion to the relevant emergency preparedness and response (EPR) material and publications [1].



Contains information on assembling an emergency 'kit' for MPs responding to radiation emergencies that includes the most important procedures and recommendations, enabling the MP to act effectively and quickly in operational conditions during radiation emergencies.

2. CONTACT AND NOTIFICATION INFORMATION

2.1. INCIDENT AND COMMAND SYSTEM

MPs are expected to participate in the response to radiation emergencies under an Incident and Command System (ICS). It is therefore important for them to have a fundamental understanding of how the ICS works.

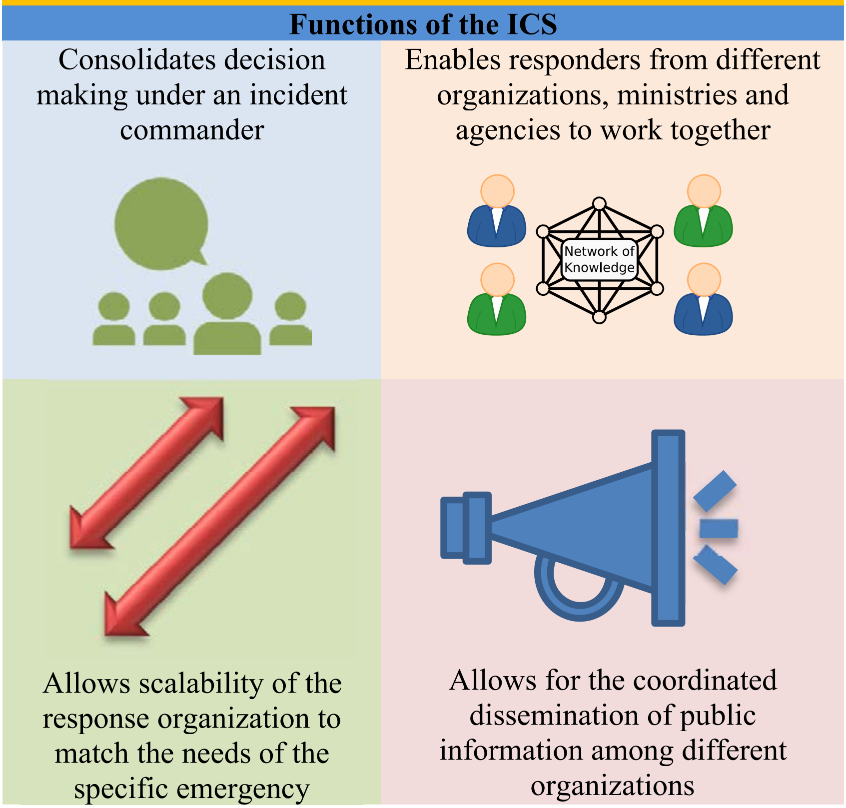


FIG. 1. Summary of the functions of the ICS [2].

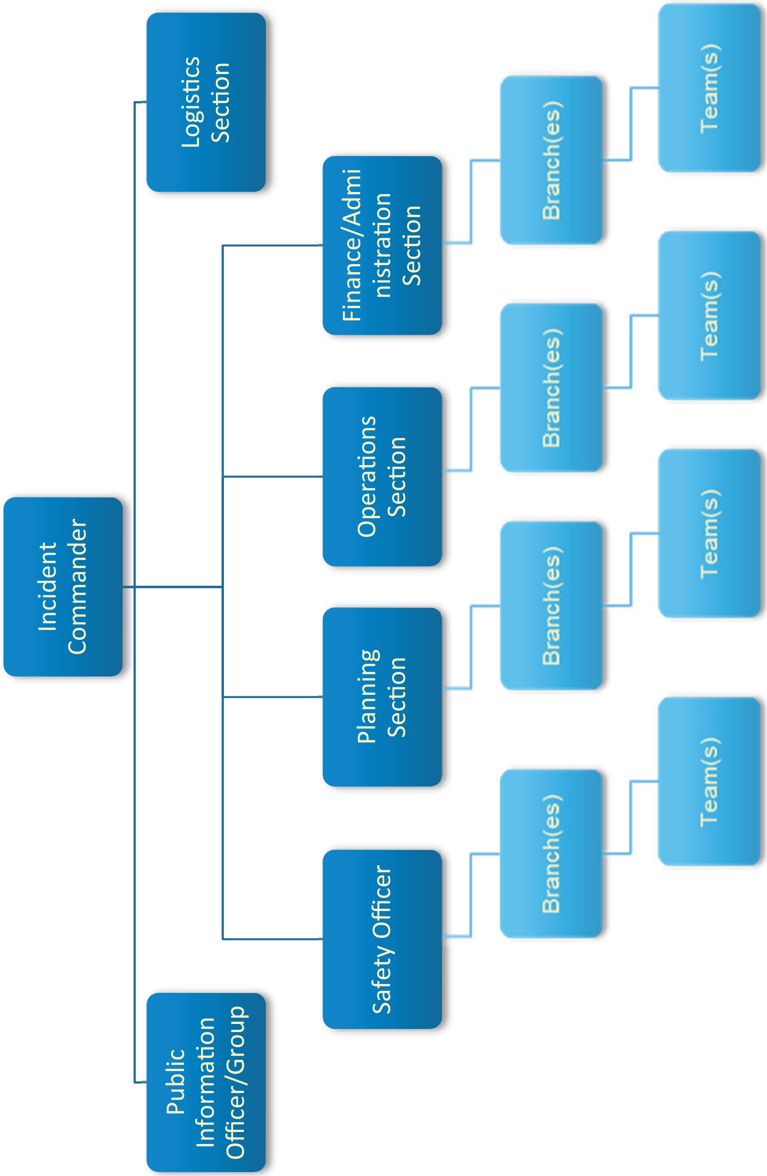


FIG. 2. Basic structure of an ICS [2] (see also Fig. 17 in Appendix I).

2.2. CHAIN OF COMMAND

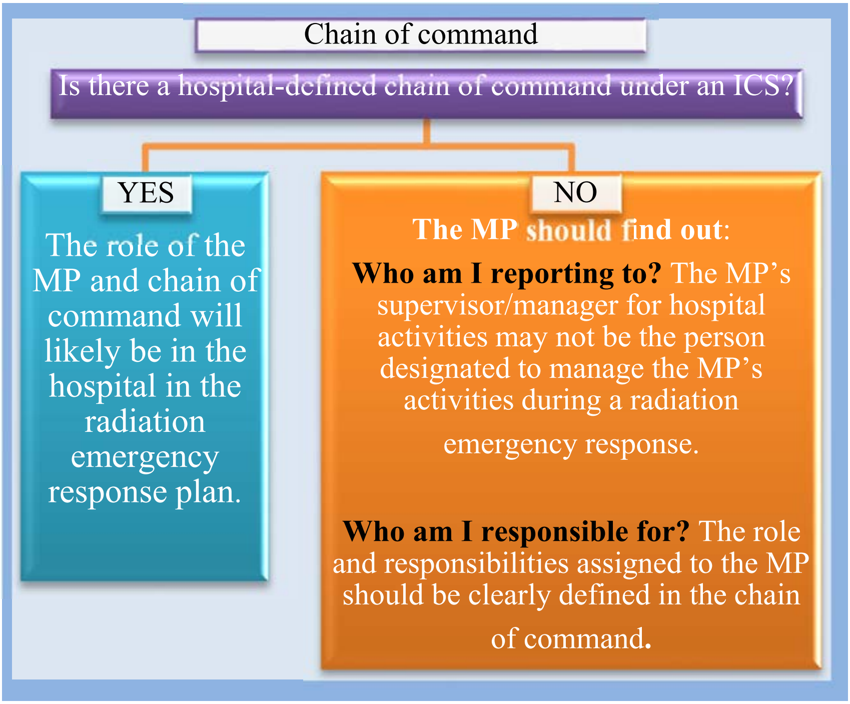


FIG. 3. The role of the MP.

2.3. EMERGENCY CONTACT INFORMATION

Table 1 is an example of the form used to collect the contact information of key parties, such as the National Competent Authority, the regulatory body, the radiological assessor (RA), the relevant fire brigade, the police department, the ambulance service, specialized response teams (if available), and the public information officer. The information needs to be kept up to date.

TABLE 1. FORM TO RECORD EMERGENCY CONTACT INFORMATION	
Relevant authority/contact in your country:	**Contact details (phone number, etc.)**
National Competent Authority (...)	
Regulatory body (...)	
Radiological assessor (...)	
Relevant fire brigade (...)	
(...)	
(...)	
(...)	
(...)	
(...)	
(...)	
(...)	
(...)	

3. RADIATION PROTECTION OF PATIENTS AND PERSONNEL

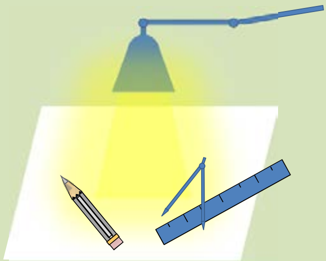
3.1. BASIC CONCEPTS

3.1.1. Possible roles of MPs in radiation emergencies

Possible roles of MPs in emergency preparedness and response

Radiological assessor (RA): As qualified experts in radiation dosimetry, MPs are able to fulfil the function of the RA [3].

Scientific and technical advisor: MPs usually act as radiation protection officers. They are able to give advice in matters related to radiation emergencies.



Trainer in radiation protection: MPs typically provide regular training in the clinical environment. In addition, those MPs who are specifically trained in radiation emergencies [1] are able to conduct training inside and outside their hospital.

FIG. 4. Possible roles of the MP as a member of the EPR team.

3.1.2. Tasks of MPs in EPR

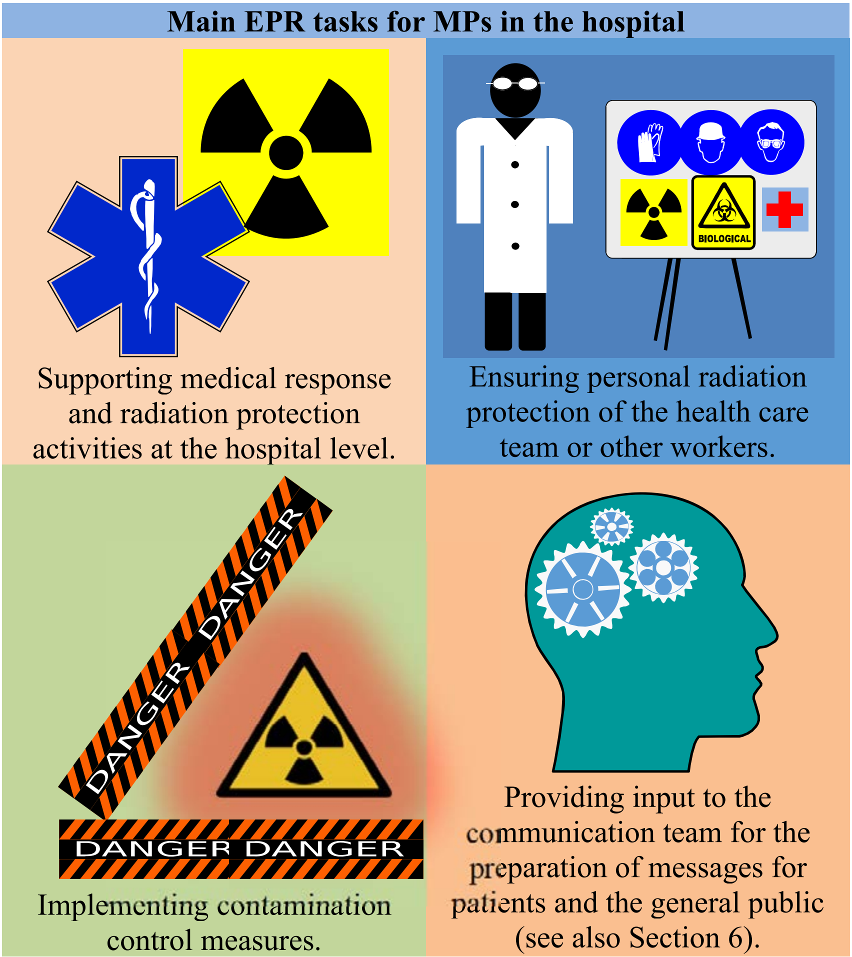


FIG. 5. Main tasks of the MP in the hospital environment during EPR.

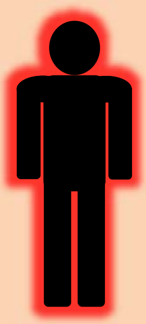
IMPORTANT!
Medical emergency care is the most important activity. Stabilizing a patient with life-threatening conditions should NOT be delayed because of the presence of contamination.

3.1.3. Types of radiation exposure

Types of radiation exposure

External exposure

Occurs when an individual is exposed to radiation from a radioactive source outside the body at a certain distance. This can lead to localized, partial or whole body external exposure (there is no radioactive contamination inside the individual). External exposure may be a consequence of direct irradiation from the source, from airborne radionuclides, or from the radionuclides deposited onto the ground and/or onto clothing and skin.



Internal exposure

Occurs when there is exposure to radiation from a source within the body (e.g. when radioactive material deposits into the body by inhalation, ingestion, absorption by intact skin or through wounds). Intake of radionuclides can be determined by in vitro in vivo bioassay techniques (internal contamination). External contamination of individuals occurs 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.

FIG. 6. Types of radiation exposure.

3.2. RESOURCES

The amount of equipment needed is dependent on the type and scale of the event. Resources include protective equipment, contamination control supplies (see also Section 4) and operational, calibrated survey meters. This equipment needs to be stored, inventoried and inspected periodically to ensure that it is operational and readily available when needed.

TABLE 2. SUGGESTED INVENTORY OF PERSONAL PROTECTIVE EQUIPMENT (PPE) [4]

Type of protective clothing	Inventory*
Protective suits (jumpsuits or gowns)	20 (large and extra-large)
Gloves (disposable)	100 pairs, various sizes
Surgical caps or bonnets	20
Particulate mask (disposable) (see also Table 3)	50
Shoe covers	100 pairs, various sizes
Tape	6 rolls for securing protective clothing
Face shields	6 (wet environment in which splashes are possible)

***The inventory depends on the size of the 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 3. SUGGESTED RADIATION DETECTION AND SURVEYING RESOURCES	
Equipment	**Inventory***
Self-reading dosimeter	4
Individual dosimetry badges (thermoluminescent dosimeters (TLDs), optically stimulated luminescent dosimeters (OSLs), etc.)	20
Survey meters for radiation exposure	2
Contamination survey equipment	2
Log book for tracking worker exposure	1
Charts for tracking patient contamination (see Appendices I–III)	20
Batteries	10 of each type needed for electronic personal dosimeter (EPD) and survey meters
Portal monitors (if available)	2
***The inventory depends on the size of the event. There will be at least one dedicated 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.**	

3.3. PROCEDURES

3.3.1. Procedures for wearing protective clothing

TABLE 4. STEPS FOR WEARING PPE [4]	
1.	Use universal precautions.
2.	Dress in protective clothing (surgical clothing, including scrub suit, gown, mask, cap, eye protection, and gloves) in the following order: (a) Put on shoe covers. (b) Put on dosimeter. (c) Put on trousers. Tape trousers to shoe covers. (d) Put on surgical gown. Tie and tape gown openings. (e) Put on surgical cap and face mask. (f) Put on inner gloves. Seal gloves to gown sleeves by tape. Gloves should be under the arm cuff. (g) Put on splash (face shield) protector. (h) Put on outer gloves (easily removable and replaced if they become contaminated).

TABLE 5. NOTES ON THE USE OF PPE

1.	Fold-over tabs at the end of each taped area will aid removal.
2.	Protective clothing is intended to keep bare skin and personal clothing free of contaminants.
3.	Protective clothing is effective in stopping alpha particles and some beta particles, but not gamma rays.
4.	Lead aprons, such as those used in X ray departments, are not recommended since they give a false sense of security — they will not stop most gamma rays.
5.	The member of the team using liquids for decontamination purposes should wear a waterproof apron.
6.	Shoe covers should be waterproof.
7.	For taping all open seams and cuffs, use masking or adhesive tape.
8.	EPDs should 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 (e.g. TLD) can be worn under the surgical gown.
9.	Protect instrumentation from contamination by covering it with thin plastic layers. ***Instruments should not be covered if alpha particle emitters are suspected.***

FIG. 7. Instruments prepared for operational use. From left to right: scintillation survey meter probe, alpha particle surface contamination detector, Geiger-Müller survey meter [5].

3.3.2. Procedures for personnel monitoring

TABLE 6. CHECKLIST FOR PERSONNEL MONITORING	
1.	Identify the resources needed based on the activities to be performed.*
2.	Recommend the assignment of EPD and individual badge dosimeters (TLDs, OSLs, etc.) and log serial numbers into the log book, if used.
3.	TLDs should be worn close to the centre of the body, beneath the protective clothing.
4.	Survey instruments should be checked at a normal background area prior to use. Consider appropriate methods to prevent instrument contamination (Fig. 7).
5.	Periodically monitor team members' hands to prevent cross-contamination.
6.	Perform frequent surveys of the work area.
7.	Survey the workers before they leave the restricted area, and log the results.
8.	Provide assistance for the safe removal of protective clothing and confirm by survey that workers are not contaminated.
*The resources will depend on the size of the 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.	

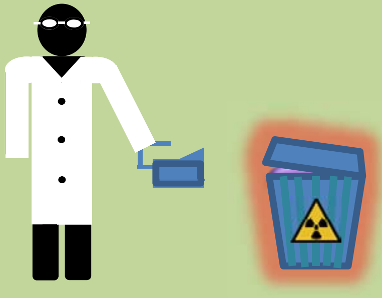
4. PREPARATION AND PROTECTION OF THE FACILITY

4.1. PREPARATION AND PROTECTION MEASURES

The MP should help make sure that:

The hospital is ready to **expeditiously** receive and process exposed and/or potentially contaminated individuals safely, efficiently, and with minimum disruption of those routine or emergency operations unrelated to the radiation emergency.

The associated radioactive waste is managed safely and effectively.



The hospital returns to normal operations soon after the emergency has ended.

FIG. 8. Measures undertaken by MPs in preparing and protecting the hospital during radiation emergencies.

Facility
People
Notification
Info

4.2. RESPONSIBILITIES OF THE MP IN SUPPORT OF THE RADIATION EMERGENCY RESPONSE

4.2.1. Before the emergency (preparation phase)

Once there is notification of a radiation emergency, patients may start arriving at the hospital in large numbers. The MP should help implement the hospital emergency response plan and ensure that the facility is protected. Specific steps include the following (adapted from Ref. [4]):

(a) Hospitals should be prepared for three groups of people arriving from a radiation 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 not injured, but who are worried about how they may have been affected, and who arrive at the hospital quickly on their own initiative. If the staff do not know how to deal with this group, these individuals may take up the hospital's resources and interfere with the treatment of the injured arriving 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.

(b) Individuals who are only externally contaminated, but not sick or injured, will be decontaminated at another facility (i.e. a reception centre), so that hospital resources are conserved for the truly sick and injured.

(c) In cases where a large number of people have potentially been contaminated, it is necessary to establish a reception centre — separate from the hospital — to perform contamination monitoring. The reception centre needs trained personnel, radiation monitoring equipment, decontamination facilities and supplies, and manual or digital record keeping supplies. Access to the reception centre should not interfere with access to the hospitals accepting casualties. Athletic fields, stadiums and community centres could be used as reception centres.

TABLE 7. ACTIONS TO PREPARE THE HOSPITAL AND STAFF TO ACCEPT AFFECTED INDIVIDUALS *(adapted from Ref. [3])*
(a) Brief health care staff that the risk from a contaminated person is negligible if they follow the personnel protection guidelines (see also Section 3).
(b) Check and prepare radiation survey meters for use: a. Perform operational checks of the instruments. b. Document background radiation levels. c. Unless the contaminant is an alpha emitter, cover the detector with a plastic sheet or surgical glove to protect the detector from becoming contaminated. d. If possible, maintain at least one instrument in the clean area for monitoring.
(c) Collect enough instruments and supplies (e.g. outer gloves, dressings) to allow replacement when they become contaminated.
(d) Follow the personnel protection guidelines (Section 3).
(e) Follow proposed operational intervention levels (OILs) for decontamination, as shown in Table 27 (Appendix III, adapted from Ref. [6]).

4.2.1.1. Equipment and supplies

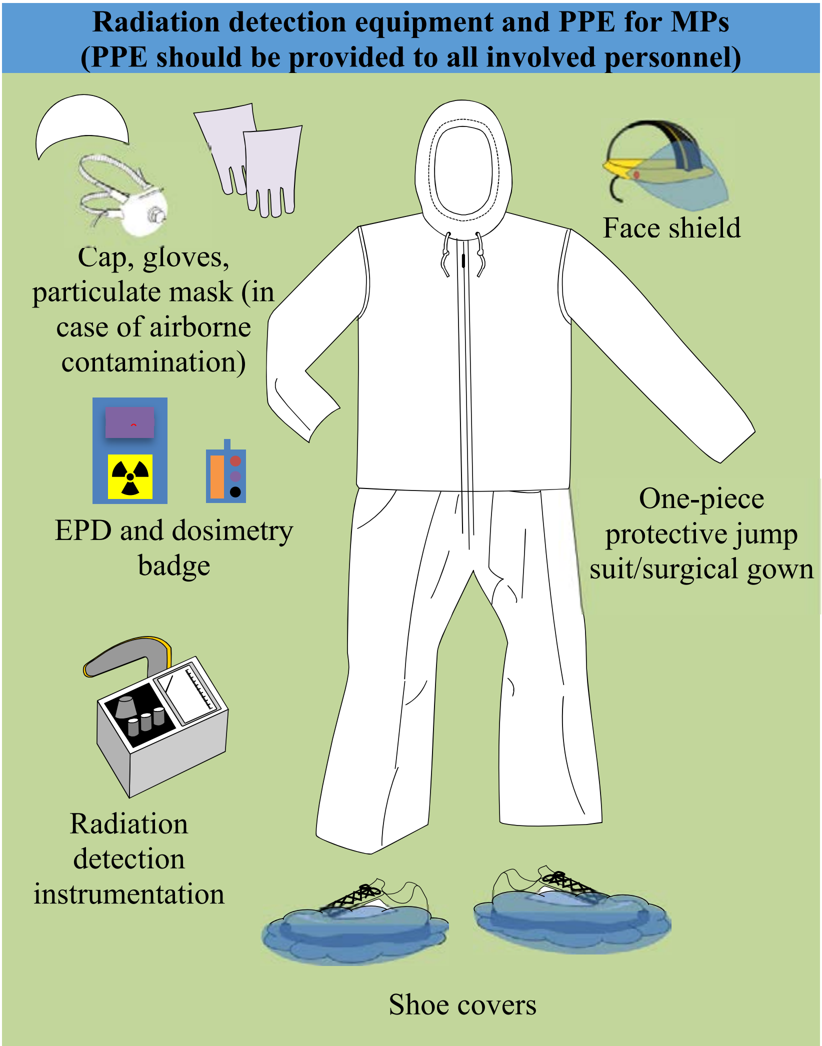


FIG. 9. MPs should be equipped with supplies for radiation monitoring of patients and staff, as well as PPE for themselves and all involved personnel (see also Section 3).

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TABLE 8. MATERIALS NEEDED DURING THE FACILITY PREPARATION PHASE	
(a)	Rolls of plastic sheeting to cover floors and unneeded equipment.
(b)	Tape for securing the plastic floor coverings in place.
(c)	Tape for marking the floor.
(d)	Rope or caution tape and warning signs for marking controlled areas clearly.
(e)	Large plastic bags for trash.
(f)	Large waste containers.
(g)	Plastic trash bags for contaminated clothing, tags and marking pens.
(h)	Small bags for contaminated personal items, with tags or marking pens.
(i)	Charts for tracking patient contamination/exposure (see Appendices I–III).

4.2.2. During the emergency (response phase)

4.2.2.1. Setting up radiological control areas

TABLE 9. SETTING UP RADIOLOGICAL CONTROL AREAS (ADAPTED FROM REF. [3]) (FIGS 10, 11)	
(a)	Include law enforcement to support redirection of the ‘worried-well’ persons (i.e. those who are concerned, but not injured), to the secondary location (i.e. reception centre) for monitoring/reassurance, as established by the resource coordinator.
(b)	Prepare and designate an **ambulance reception area** and **treatment area** for receiving casualties according to the hospital plan for medical response to radiation emergencies.

(c) Each hospital has to consider its individual situation and respective facility design. See Fig. 17 in Appendix I for sample set-ups of 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 emergent medical care.

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

(f) Re-route the traffic of other (non-radiation emergency) patients (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 non-radiation emergency patients.
- Remove or cover equipment that will not be needed.

(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; stock plastic bags of varying sizes, as well as labels, for personal effects; and stock 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 treatment area entrance.
(m)	Establish a control line at the entrance to the decontamination room. Use wide tape to clearly mark the floor at the entrance to the room to differentiate the controlled (contaminated) side from the non-controlled (uncontaminated) side.
(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 should be surveyed and decontaminated (if necessary), unless the ambulance personnel need to return to the scene immediately for life saving response actions (see Section 5 for more information on decontamination of patients). • Surveying the ambulance may be delayed until the end of the shift or until all the patients have been 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 exiting the contaminated area.
- Survey medical equipment for contamination before removing it from the contaminated area.

NOTE: 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 radiation 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.

4.2.2.2. Workflow and prioritization at the emergency scene

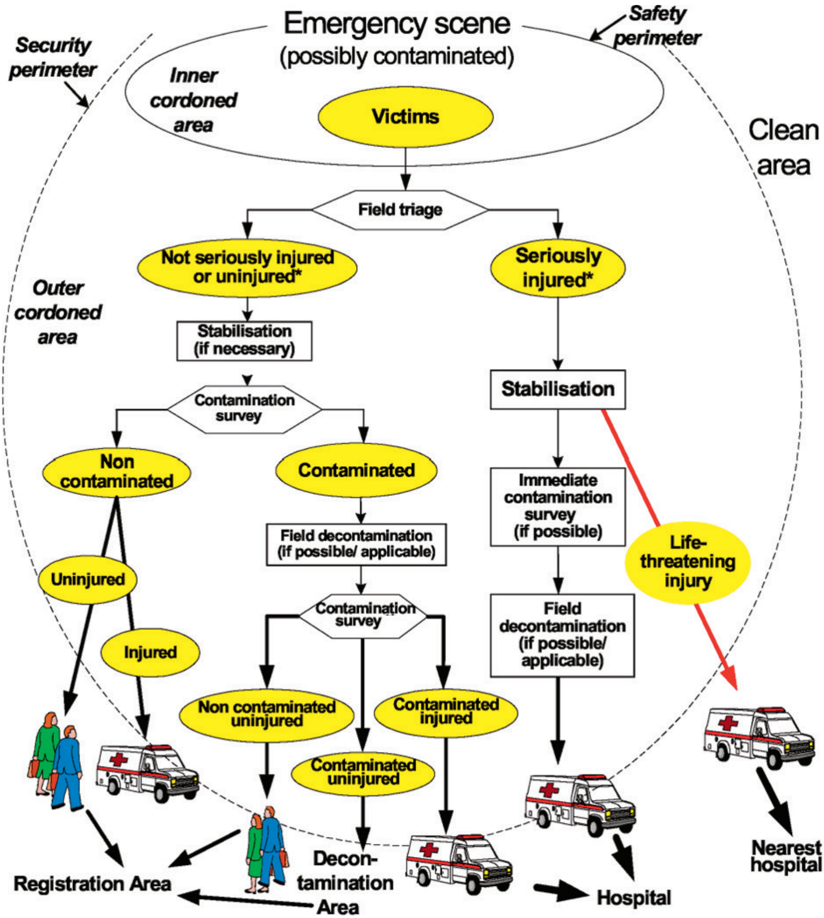

FIG. 10. Diagram of an emergency scene [4].

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4.2.2.3. Duties of team members during response to radiation emergencies

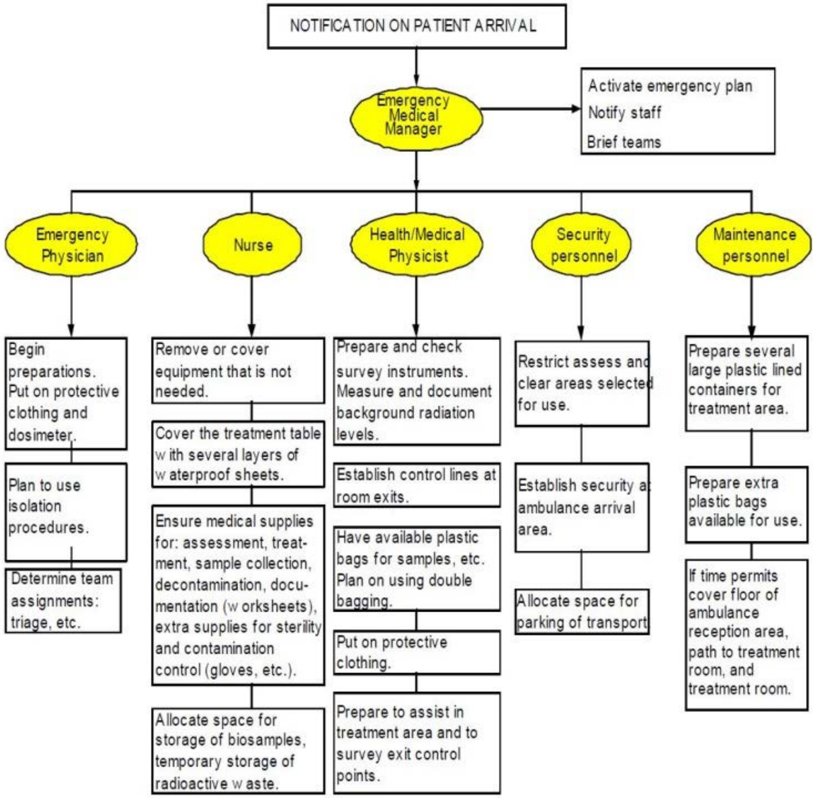

FIG. 11. Preparation for contamination control by the hospital emergency department response team [4].

4.2.3. After the emergency (recovery phase)

The MP can lead the radiological survey of the hospital areas and the decontamination of those areas, if needed; 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 Table 10).

4.2.3.1. Waste management

TABLE 10. ACTIONS RELATED TO WASTE MANAGEMENT DURING RADIATION EMERGENCIES	
(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 should 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)	Ensure that the final disposal by the hospital of waste from a radiation emergency is consistent with the national policy and strategy for management of radioactive waste.
(h)	If applicable, coordinate handling and processing of this waste with law enforcement officials and forensic experts.

4.2.3.2. 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.
- Make sure all emergency equipment is restored and inventories are restocked and prepared for use in the event of another radiation emergency.

5. EARLY DOSE ASSESSMENT AND DECONTAMINATION

5.1. PURPOSE

Early dose assessment seeks to guide medical management by determining the magnitude of radiation dose rather than specific radiation doses.

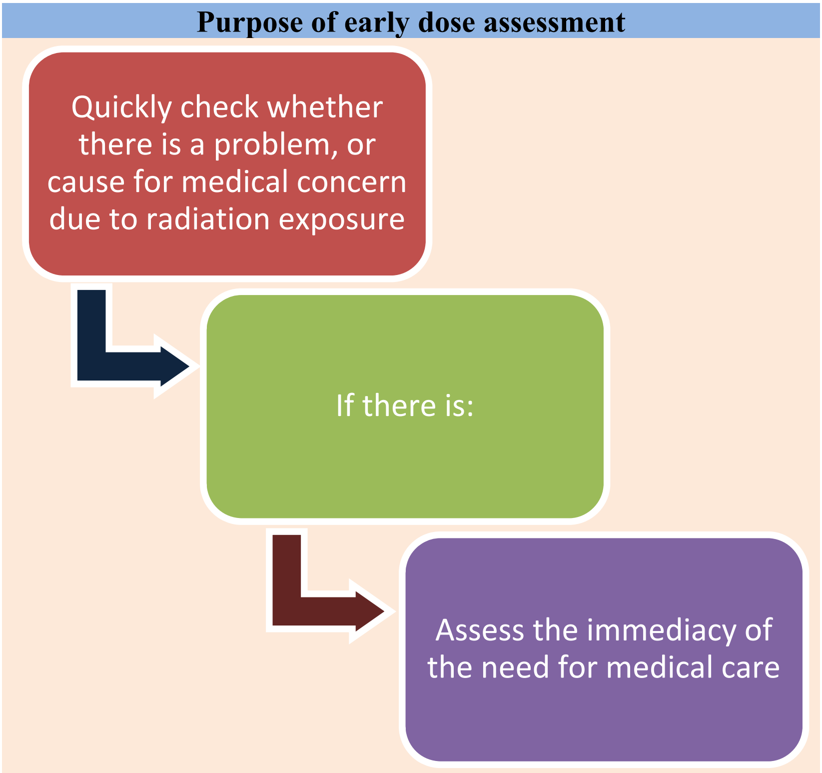

FIG. 12. Visual representation of the early dose assessment rationale.

5.2. INITIAL EXTERNAL DOSE ASSESSMENT

5.2.1. Theoretical background for early external dose assessment

Many variables need to be considered when performing initial external dose estimations. These variables include:

- Exposure time;
- Distance of the exposed individual from the source;
- Activity of the involved source;
- Potential shielding that may be encountered;
- The radioisotope concerned.

Identification of the source activity and isotope is usually fairly straightforward.

The inverse square law is often the most useful when calculating doses at a given distance from a source. This equation can also be written as:

$$D = \frac{\Gamma A t}{d^2} \quad (1)$$

where:

D is the dose in mSv (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 in megabequerel (MBq);
t is the exposure time in hours (h);
d is the distance in centimetres (cm);
and Γ is the gamma ray constant in $mSv \cdot cm^2 \cdot h^{-1} \cdot MBq^{-1}$ (isotope specific).

As a rule of thumb, the inverse square law may be applied when the distance from the source is at least three times the longest dimension of the source [7].

Gamma constants for selected commonly encountered isotopes are given in Table 11.

TABLE 11. GAMMA CONSTANTS OF COMMON ISOTOPES ENCOUNTERED IN RADIATION EMERGENCIES [7, 8])

Isotope	Gamma constant ($mSv \cdot cm^2 \cdot h^{-1} \cdot MBq^{-1}$)*
Cobalt-60	3.48
Caesium-137	0.927
Iridium-192	1.24
Radium-226	2.23
Selenium-75	0.548
***Multiply ($mSv \cdot h^{-1} \cdot MBq^{-1}$) by 3.7 to obtain ($R \cdot h^{-1} \cdot mCi^{-1}$)**	

IMPORTANT!

Proper dose estimation depends on accurate information on the irradiation conditions. For high activity sources, in particular, slight differences in distance or exposure time may have a large impact on the estimated dose. **It is therefore very important to obtain as much information about the event as possible. It is advisable to gather the information pertinent to dose assessment as soon after the event as possible, before it is forgotten.**

IMPORTANT!

Taking all available information into account, it is usually advisable to be **realistically conservative** in estimating the magnitude of the dose. An estimate that tends toward the higher realistically expected dose is usually more beneficial for treatment planning purposes than underestimating the dose.

5.2.2. Early external dose assessment calculation example

Example calculation of external dose to point A

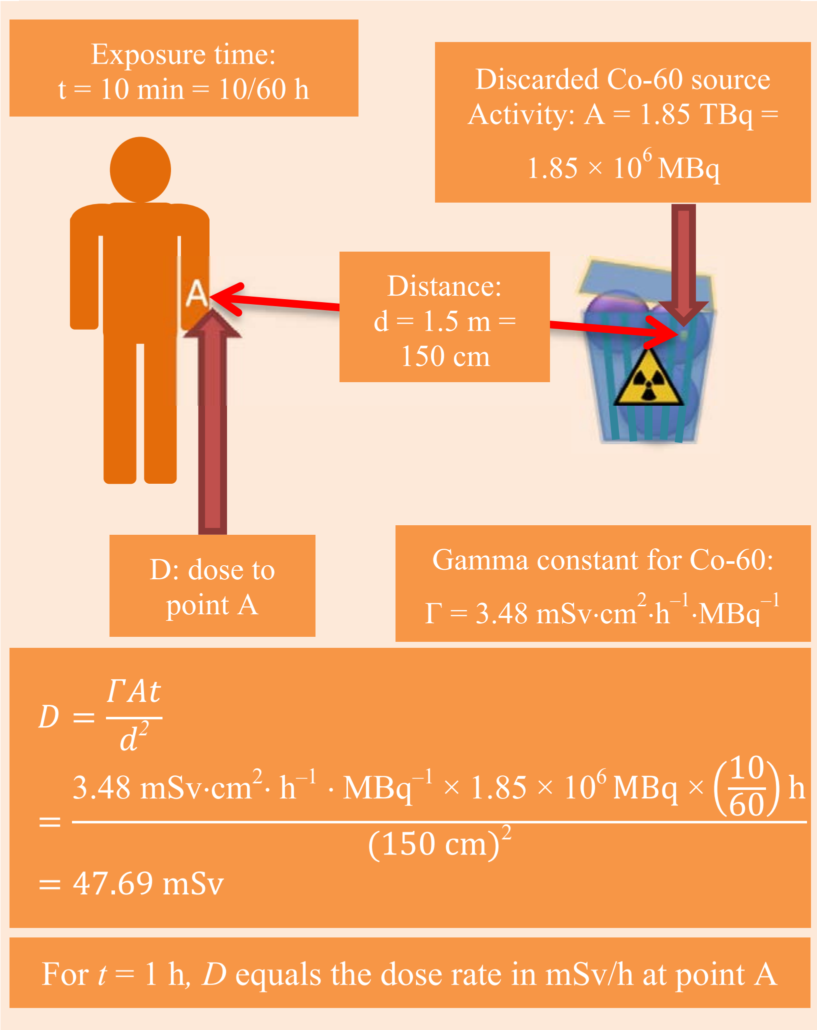

FIG. 13. Example of the application of the inverse square law to calculate dose to a point A in distance d from a source.

Dose
Facility
People
Notification
Info

5.2.3. Contact doses

Contact doses — when an individual physically touches the source — require close evaluation. Due to rapid attenuation with distance (inverse square law), 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 buildup will 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 occurs primarily from 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. Information about common gamma emitters can be found in Ref. [7].

It is important for the physician to know which tissues may be primarily affected, and which tissues may not be affected at all. So, as is the case in other medical physics applications, early assessment of accidental radiation doses has to take into account 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.

5.2.4. Example of finger dose assessment

Quick assessment of contact doses is performed using Eq. (1) for very small source-to-target distances. Suppose a small physical size 1.85 TBq (50 Ci) ^{192}Ir source is held by an individual for 1 min. The dose to the fingers (assuming a distance of about 2 cm) would be calculated as follows:

Dose

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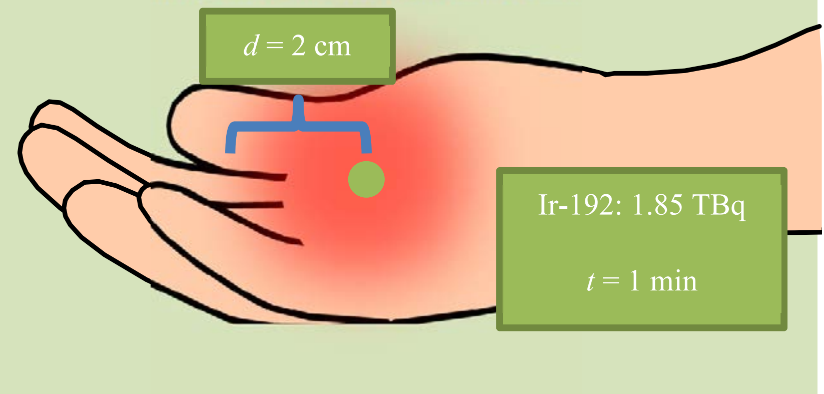
Example of calculation of dose to the fingers



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

$$= \frac{1.24\ \text{mSv}\cdot\text{cm}^2\cdot\text{h}^{-1}\cdot\text{MBq}^{-1} \times 1.85 \times 10^6\ \text{MBq} \times \left(\frac{1}{60}\right)\text{h}}{(2\ \text{cm})^2}$$

$$= 9558.33\ \text{mSv} \sim 9.56\ \text{Sv}$$

This value represents a very high dose to the fingers, and it is expected to be associated with some kind of skin injury. Tables 13 and 14 provide threshold doses for the onset of skin injury manifestations.

FIG. 14. Example of the application of the inverse square law to calculate dose to the fingers of a person holding a source.

5.2.5. Dose range thresholds for clinical manifestations

As the situation evolves, clinical manifestations will begin to define the dose range of the radiation doses received. Observable radiation induced clinical manifestations are related to threshold doses (Tables 12–14) and usually take time to fully develop [7, 8].

Dose
Facility
People
Notification
Info

TABLE 12. SKIN INJURY THRESHOLDS VERSUS ACUTE DOSES (ADAPTED FROM REF. [7])

Dose (Gy)	Effect	Timing* (time post-exposure)
3	Epilation	14–21 days
6	Erythema	Early, 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

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

TABLE 13. THRESHOLDS FOR ACUTE RADIATION SYNDROMES AND RELATED SYMPTOMS (ADAPTED FROM REF. [7])

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

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

In addition to the threshold effects described in Tables 12 and 13, one of the most important tests is that for lymphocyte kinetics, which can be used as an indicator of radiation dose [9, 10].

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 14). The physician should evaluate the patient's signs and symptoms, comparing these with the information provided by the MP. Discrepancies will be discussed, with emphasis on the current medical situation (clinical status of the patient).

TABLE 14. ABSOLUTE LYMPHOCYTE CONTENT IN THE FIRST TWO DAYS AFTER RADIATION EXPOSURE AND SURVIVAL PROGNOSIS [4]

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

Relevant information for the dose assessment of overexposed individuals is also provided by cytogenetic dosimetry, also called biological dosimetry, the gold standard technique 'dicentric assay', based on the analysis of solid stained dicentric chromosomes and other chromosomal aberrations in the lymphocytes [9]. Chromosome aberration analysis in peripheral lymphocytes of individuals exposed to radiation is currently used as a validated method to estimate the absorbed dose [4].

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 (CBMN) [9].

Important: most of the biological dosimetry assays require several days to provide the dose estimations.

5.2.6. Possible pitfalls, additional considerations

In order to provide effective support to the medical staff, the MP should also be aware of potential pitfalls associated with dose estimation in accident situations [7]. 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 [7].

Early dose estimations should 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 [7]. In many cases, the exact dose may never be known. Medical management should require continuing communication between health care and radiation protection professionals to ensure the proper response.

Note that physical dosimetry (TLDs, OSLs, etc.) only measures the dose at 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.

The dose assessment methods provide one input, frequently a very important one, in the compendium of information that needs to be collected and considered when a nuclear or radiological emergency is investigated [9].

5.3. INITIAL DOSE ESTIMATION FOR INTERNAL EXPOSURE

Internal radiation doses can be extremely complicated to determine. However, early dose magnitude estimation for inhalation or intakes from wounds can often be performed fairly easily.

The aim of the assessment of internal contamination for purposes of radiation safety is to quantify the incorporation of the 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 [10].

5.3.1. Inhalation

Nasal swabs, if taken within the first hour post-intake, represent roughly 10% of the intake [11].

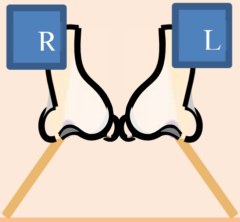
Ten per cent of the inhalation intake can be estimated using nasal swabs if the swabs are collected within the first hour after intake.

5.3.1.1. Calculation of committed dose equivalent through estimation of inhalation intake

TABLE 15. CALCULATING COMMITTED DOSE EQUIVALENT BY ESTIMATING INHALATION INTAKE	
Step 1	Swab the anterior portion of the nose using a separate swab for each nostril
Step 2	Measure the counts per minute (counts/min) for each swab with a pancake detector. The counts/min from both nostril swabs are added together for the total result.
Step 3	In turn, the total counts/min are multiplied by 10 to obtain the number of disintegrations per minute (dis/min), assuming a 10% photon detection efficiency for the pancake probe.
Step 4	Because nasal swabs represent 10% of the total intake, the dis/min is multiplied by 10 to obtain the total dis/min corresponding to 100% of the intake.
Step 5	The committed effective dose can be estimated by multiplying the total dis/min by the appropriate coefficients tabulated below (a more complete set of coefficients for different nuclides and age groups can be found in table XII-B1-2 in Ref. [4]).

TABLE 16. INHALATION: COMMITED EFFECTIVE DOSE PER UNIT INTAKE (e^{Inh}) FOR ADULT MEMBERS OF THE PUBLIC FOR THE MOST COMMON RADIONUCLIDES ENCOUNTERED *(adapted from table XII-B1-2 in Ref. [4])*		
Nuclide	**Substance/type***	$\mathbf{e^{Inh}}$
Co-60	M	1.0E-08
Co-60	S	3.1E-08
Sr-90	F	2.4E-08
I-131	F	7.4E-09
Cs-137	F	4.6E-09
Ra-226	M	3.5E-06
U-238	S	8.0E-06
Pu-239	S	1.6E-05
Am-241	M	4.2E-05
When the nuclide is unknown, assume the following [7]: • If it is an alpha emitter, assume it is Am-241. • If it is a beta emitter, assume it is Sr-90. • If it is a gamma emitter, assume it is Cs-137.		
*Remarks: F, M and S, respectively, aerosol of types fast, medium and slow with AMAD 1 µm. **Type F (Fast):** Forms that may be rapidly absorbed. Examples are all the commonly occurring compounds of caesium and iodine. **Type M (Medium):** Examples are compounds of radium and americium. **Type S (Slow):** Examples are insoluble compounds of uranium and plutonium.		

Example of committed dose calculation using inhalation intake estimation



Event: An individual inhales fumes containing Cs-137

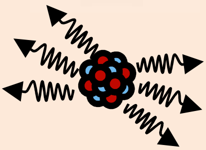
Step 1: Swab each nostril **separately, within an hour** of inhalation

Step 2: Measure swab counts and calculate $counts/min_{total}$

$counts/min_{total} = counts/min_{right} + counts/min_{left}$

$= 4800$ counts/min + 5200 counts/min $= 10^4$ counts/min

Significant differences between the count rates of each individual swab may indicate cross-contamination (finger, hand, etc.)



Step 3: Calculate dis/min:

$dis/min = counts/min_{total} \times 10$
$= 10^4 \times 10 = 10^5$

Step 4: Calculate total dis/min

$Dis/min_{total} = dis/min \times 10$
$= 10^5 \times 10 = 10^6$

Step 5: Calculate committed dose by looking up the e^{Inh} value for Cs-137 in Table 16.
Convert dis/min to Bq by using the formula: **1 dis/min = 0.016 666 67 Bq**

Committed dose $= dis/min_{total} \times e^{Inh}$
$= 10^6 \times 0.016\,666\,67$ Bq $\times 4.6 \times 10^{-9}$ Sv Bq^{-1} $= 76.67$ µSv

FIG. 15. Example of committed dose calculation by estimating inhalation intake.

5.4. DECONTAMINATION

Ensure that the patient is medically stable prior to commencing decontamination procedures.

External decontamination will follow the following priority order:

- **First priority: Decontaminate open wounds;**
- **Second priority: Decontaminate facial orifices;**
- **Third priority: Decontaminate intact skin.**

TABLE 17. EFFECTIVE DECONTAMINATION OF PATIENTS: TIPS AND PROCEDURES	
(a)	Ensure that the material being decontaminated is not being transferred to previously decontaminated areas.
(b)	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 should be implemented, if necessary.
(c)	The patient should receive a simple examination upon entry into the health care facility. This first examination should inform personnel of the presence or absence of contamination, and its general location and magnitude. This information will help inform staff of potential issues (e.g. contamination in the breathing zone or upper chest may indicate the potential for an inhalation intake).
(d)	Once patient clothing has been removed, a detailed survey should be performed to identify areas of contamination. The patient should be protected from contamination transfer during the removal of contaminated clothes.
(e)	The removed clothing should be retained for radioanalysis to determine the contaminating radioisotope.
(f)	Excreta samples should be collected for bioassay to verify the presence or absence of potential internal dose issues.

(g) 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. Warm water and soap are excellent decontaminating agents for intact skin.

(h) When decontaminating intact skin, care should be taken to avoid abrading the skin surface, thus creating a potential intake route.

(i) 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 container (see Fig. 16). 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. 16. Wound decontamination procedure and dress for staff and patient *[1].*

(j) It is generally recommended that each area be decontaminated separately using the easiest effective method resulting in the least runoff possible. Showering the whole body when contamination was 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.

5.4.1. Wounds

Wounds are another major intake route from radiation incidents. The Radiation Emergency Assistance Centre/Training Site has published Dose Coefficients for Intakes of Radionuclides via Contaminated Wounds, from which derived reference levels (DRLs) have been tabulated for various radionuclides [12–15]. This information can be used as a comparison point for dose magnitude estimation.

The Centers for Disease Control and Prevention (CDC), in the United States of America, has developed an online tool to help assess internal doses based on external measurements taken with a number of handheld instruments [16]. More detailed information about early dose magnitude estimation, including examples of the use of these methods, can be found in Refs [7, 17–21].

5.5. DEFINITIVE DOSE ASSESSMENT AND FOLLOW-UP

For definitive assessment and long term treatment decisions, it is essential that physicians, physicists and other professionals employ a **multidisciplinary approach** to providing medical support, dose estimations, and psychological support as well as to updating registration of individuals and arranging for medical follow-up [10].

During radiation emergencies, MPs should ensure the collection and compilation of good quality data/information, which will be used at a later stage to decide long term treatment and actions for patients.

Due to the non-urgent nature of the definitive dose assessment and long term follow-up actions, the details are not included in this publication. The methodology proposed is included in Ref. [4].

5.6. ACTIONS RELATED TO LONG TERM MEDICAL FOLLOW-UP

People who might be potentially affected should also be considered. While this is usually not considered an acute medical concern, MPs supporting the response to radiation emergencies may be called upon to help inform decision makers of information pertinent to the protection of the public.

Depending on the type and scale of the radiation emergency, in addition to any 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 some dose of 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 should 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 if any members of the public will need long term medical follow-up. MPs may be asked to provide assistance in this process.

5.7. TOOLS FOR EMERGENCY DOSE CALCULATIONS

There are tools available online for dose calculations. Table 18 provides information and links to the most popular.

TABLE 18. ONLINE TOOLS AND PROGRAMS FOR INITIAL DOSE ASSESSMENT IN RADIATION EMERGENCIES	
Rad Pro Calculator [22]	Provides beta and gamma dose rate information, both shielded and unshielded, in addition to other dosimetric information, http://www.radprocalculator.com
Armed Forces Radiobiology Research Institute Biodosimetry Assessment Tool program [23]	Assesses the radiation dose based on biological indicators such as lymphocyte counts and time to emesis, https://www.usuhs.edu/afrri/biodosimetrytools
Radiation Emergency Medical Management dose calculator [24]	Assesses the radiation dose based on biological indicators such as lymphocyte counts and time to emesis, https://www.remm.nlm.gov/ars_wbd.htm
While these methods provide initial guidance on dose assessment, they should not replace the standard methods for dose assessment of individuals.	

5.8. SUMMARY

Rapid dose estimation should inform, not decide, the medical management of victims of radiation incidents. Definitive dose assignment will 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 should 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.

6. EFFECTIVE PUBLIC COMMUNICATION

6.1. OBJECTIVE

The objective of effective public communication is to mitigate the effects of radiation emergencies on people and the environment, by providing individuals with the relevant information they need, at the given moment.

6.2. ROLE OF THE MEDICAL PHYSICIST IN COMMUNICATION DURING RADIATION EMERGENCIES

MPs can act as part of a larger mechanism providing technical input as subject matter experts in accordance with the communication strategy of the organization, and in coordination with responsible communication professionals.

In general, the MP is not solely responsible for developing and implementing a communication strategy.

If communication experts/resources are not available, more information may be found in Refs [25–27].

6.3. KEY CONSIDERATIONS

6.3.1. Identification of target audiences

For every target audience it is important to identify and prioritize issues that need to be addressed. MPs are encouraged to try to assess the average level of understanding/knowledge of each group in order to tailor messages to the different target audiences.

TABLE 19. TARGET AUDIENCES USUALLY ENCOUNTERED IN THE HOSPITAL DURING RADIATION EMERGENCIES
• Affected members of the public (patients) at the hospital.
• Relatives (next of kin) of affected individuals will need:
— Professionals involved in the response (e.g. emergency medical management physicians and nurses);
— Hospital based staff not directly involved in radiation emergencies response;
— Interested parties at different levels who may be part of the response mechanism (e.g. hospital managers);
— Reporters and the press.

6.3.2. Psychosocial aspects of radiation emergencies

- Understanding emotional factors contributing to risk perception is basic to any risk communication programme [28].
- 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 advice on psychological first aid can be found in a World Health Organization publication [26].

6.3.3. Developing appropriate messages

Generally, MPs should work with communication specialists to develop appropriate messages for target audiences. Note that people will be under stress and will have more difficulty comprehending than usual.

Key messages should be concise points that can be easily remembered by the public and integrated into multiple information products and formats. **They will include action steps [27].**

Example

In the case of a lost radiation source, the message must be concise and include action prompts:

"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."

A useful set of considerations to be taken into account when creating appropriate messages during emergencies is provided below.

TABLE 20. CONSIDERATIONS WHEN CREATING MESSAGES ADDRESSED TO THE PUBLIC DURING RADIATION EMERGENCIES [27]

(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 in the gaps.
(c)	**Be credible.** Honesty and transparency help maintain credibility.
(d)	**Express empathy.** People who suffer need their suffering to be acknowledged. Empathy builds trust.
(e)	**Promote action.** Action calms anxiety by keeping individuals occupied with meaningful and useful actions, while promoting their sense of control after a scary incident.
(f)	**Show respect.** Respect promotes cooperation.

Communication
Dose
Facility
People
Notification
Info

7. MEDICAL PHYSICIST'S 'GRAB–AND–GO' KIT

MPs responding to radiation emergencies will need equipment and tools for radiation protection and for performing their work on the scene. For this reason, it is essential that hospitals maintain a specific 'Grab–and–Go' kit for the responding MPs in a radiation emergency. This kit is meant to be maintained in operational condition. Processes ensuring the kit's operational condition should be in place at the hospital.

The following tables provide a list of contents for the Grab–and–Go kit. Depending on local expected operational conditions, the kit may need to contain items that are not included in this list. Ideally, the team should include more than one person. However, the list of items is provided for use by one person.

Make sure detectors and dosimeters are calibrated. A mechanism should be in place to ensure routine replacement of items as needed (batteries, individual dosimeters, etc.).

Kit
Communication
Dose
Facility
People
Notification
Info

7.1. DOSIMETERS

TABLE 21. TYPES OF DOSIMETERS NEEDED FOR RESPONSE TO RADIATION EMERGENCIES

Item	Description	Quantity
EPD[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 (AA, AAA, or other)	4 sets
Individual dosimetry badges (like those used in hospitals)[b]	TLD, OSL, film or EPD	1

[a]Pocket ionization chambers may be used as alternatives. Be aware of limitations in cumulative dose and dose range capabilities.
[b]These will need to be replaced periodically.

7.2. INSTRUMENTATION

TABLE 22. TYPES OF INSTRUMENTATION NEEDED FOR RESPONSE TO RADIATION EMERGENCIES		
Item	Description	Quantity
Survey meter for ambient dose detection (beta and gamma radiation detection)	Survey meter (ionization chamber, Geiger-Müller or scintillation detector) with window allowing detection of beta radiation: • Dose rate: 0.1 µSv/h to 1 Sv/h; • Audible and visual alarms for high dose rate; • Lightweight and rugged; • Standard batteries; • Quick response time.	2
Contamination meter with probe for surface contamination detection	Geiger-Müller probe will be less accurate above 100 000 counts/min. Typical background: 27–575 counts/min. *(A survey meter for alpha particle detection may be required in some cases.)*	2
Wipe test kits	Wipes for sampling of removable contamination should be available	20
Critical spare parts	Cables, extra probes (if any), batteries.	2 sets
Plastic bags	Transparent plastic bags of an adequate size to contain the instruments/probes that need to be protected from contamination.	50

Some of the equipment described in Table 22 requires special training. Proposed quantities of consumables are based on the assumption that replenishment is possible within 48 hours

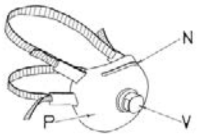
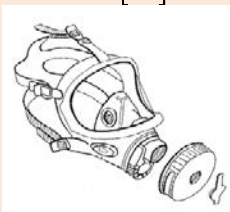
7.3. BASIC PROTECTIVE EQUIPMENT

TABLE 23. BASIC TYPES OF PROTECTIVE EQUIPMENT NEEDED FOR RESPONSE TO RADIATION EMERGENCIES

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 Tyvek suits should be used for most conditions in the controlled areas of a hospital. Additional suits should be included in the kit in the event of failure, or to be provided to other members of the team.	2
Gloves	Lightweight disposable polyethylene or latex gloves.	25 pairs
Shoe covers/ overshoes	Disposable, single size, foot-shaped plastic bags with elastic openings: • Personal footwear may be worn underneath. • Protection from minor spills.	25 pairs
Surgical caps		25
Sealing tape	Preferably waterproof tape that is not affected by liquids.	25 m or more
Lightweight plastic face shields		25
• Be aware that other hazards may be present (e.g. chemical, electrical) and 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 hours.		

7.4. PROTECTIVE EQUIPMENT TO CONSIDER

TABLE 24. TYPES OF PARTICULATE MASKS NEEDED FOR RESPONSE TO RADIATION EMERGENCIES

Item	Description	Quantity
Disposable masks to be handed out and protect people at the scene from radionuclide inhalation	Filtering face piece (FFP) respirators. FFP3 class provide adequate protection for either low risk or limited risk areas or for short exposures within the specified limits [29].  	20
High specification masks for use by the responding MP (in case of deployment to a highly contaminated area). **Use of such equipment requires specialized training.**	Full face mask respirators. Made of moulded rubber or plastic. Cover the entire face. Held in place with adjustable head harnesses [29]. 	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 that masks come with appropriate filters for any contaminants that might be encountered (particulate or charcoal filters).	4 sets

Kit
Communication
Dose
Facility
People
Notification
Info

- Be aware that other hazards may be present (e.g. chemical, electrical) and ask for more information from on-site safety officer(s).
- 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 hours.
- Some of the equipment described requires special training.

7.5. INFORMATIONAL MATERIAL

TABLE 25. TYPES OF INFORMATIONAL MATERIAL AND FORMS NEEDED FOR RESPONSE TO RADIATION EMERGENCIES

Item	Description	Quantity
Data sheet with recommended operational intervention level (OIL) values for skin contamination [6]	See OIL charts in Appendix III	1
Work sheet for on-scene contamination monitoring [4]	See Fig. 25, Appendix III	50 copies +1 electronic version
Work sheet for patient radiological survey [4]	See Fig. 26, Appendix III	50 copies +1 electronic version
Work sheet for patient dose assessment [4]	See Fig. 27, Appendix III	50 copies +1 electronic version
Inventory checklist	A list of all items contained in the Grab–and–Go kit	1

Instruction manuals/flash cards for measurement equipment	Laminated pages containing quick start and user 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 under emergency conditions.	1 for each device
Emergency phone numbers, radio frequencies (in case radios are used)	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

7.6. MISCELLANEOUS EQUIPMENT

TABLE 26. MISCELLANEOUS TOOLS AND ITEMS NEEDED FOR RESPONSE TO RADIATION EMERGENCIES

Item	Quantity
Scissors	1
Pliers	1
Cutter/knife	1
Flashlight (hand wound)	1
Pens/pencils	2
Notebook	1

Plastic foil	1 roll
Cellular phone with charger	1
A copy of this publication	1 + 1 electronic version

Appendix I
SAMPLE DOCUMENTATION

This appendix complements Section 4.

I.1. SAMPLE HOSPITAL ENTRANCE SET-UP

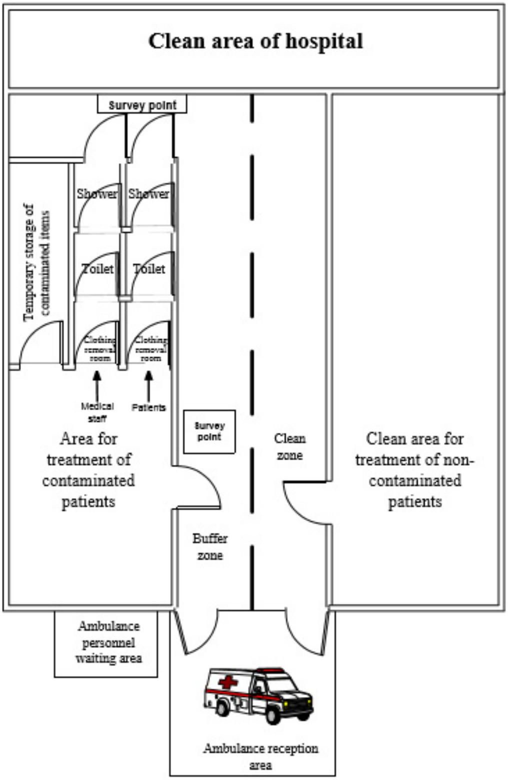


FIG. 17. Sample hospital entrance set-up [4].

I.2. SAMPLE TAG AND 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. 18. Tag for contaminated items [30].

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. 19. Receipt for contaminated items[30].

Appendix II
WORKSHEETS

This appendix complements Section 5.

II.1. REGISTRY FORM FOR PERSON 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   Time: __________

☐ Public Health Advisor

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. 20. Sample of worksheet for registry of a person involved in a radiation emergency [4].

II.2. MEDICAL INFORMATION FORM FOR PERSON 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. 21. Sample of worksheet for medical information [4].

II.3. FORM FOR THE RESULTS OF DOSE ASSESSMENT OF A PERSON 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. 22. Sample of a worksheet for the results of dose assessment of a person involved in a radiation emergency [4].

Appendix III
OPERATIONAL INTERVENTION LEVELS

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

TABLE 27. RECOMMENDED ACTION FOR (OILs) FOR SKIN CONTAMINATION (OIL 4)
(adapted from Ref. [6])

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 to 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 NOT 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.

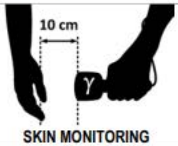


FIG. 23. Default OIL4 chart for skin dose rates (reproduced from Ref. [31]).

A person with a concentration of radioactive material on the skin greater than OIL4 should be registered for medical screening to determine if any further actions are needed. This does not mean that the person will suffer any adverse effects, but it is prudent to conduct further medical examinations.

It should be kept in mind that health effects resulting from radiation exposure can only be assessed properly by experts. Others, such as local physicians, usually do not have the expertise needed to make such assessments. The risk from radioactive material on the skin is small and comes primarily from unintentionally (inadvertently) eating radioactive material that has gotten on the hands. Individuals who may have radioactive material on them because they were near the nuclear power plant or came from an evacuated area should take the following basic precautions:

(a) Keep their hands away from their mouth until they have been washed.

(b) Remove their outer clothing and shower as soon as possible and then dress in clean clothing. The removed clothing needs to be stored in a closed bag until it can be dealt with under the direction of local officials.

If the associated levels of radioactive material on the skin are below the OIL4 values, they are not a significant health risk. However, washing hands, showering and changing clothing as soon as possible is always prudent [32].

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. 24. Default OIL chart for skin dose rates (reproduced from Ref. [31]).

A thyroid dose rate above OIL8 indicates that the person has inhaled or ingested enough radioactive iodine to require a medical screening. Individuals whose thyroid dose rate is greater than OIL8 should be registered for a medical screening to determine whether any further actions are needed. This does not mean that the person will suffer any adverse effects, but it is prudent to conduct further medical examinations.

It should be remembered that health effects resulting from radiation exposure can only be assessed properly by experts.

Others, such as local physicians, usually do not have the expertise needed to make such assessments.

III.2. WORKSHEET FOR ON-SCENE CONTAMINATION MONITORING

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

Surveyed by: ______________________________ (Full name) Date: __________

Provide to: ☐ Emergency Medical Responder Time: __________

Name of victim: ______________________________ Sex: ☐ M ☐ F

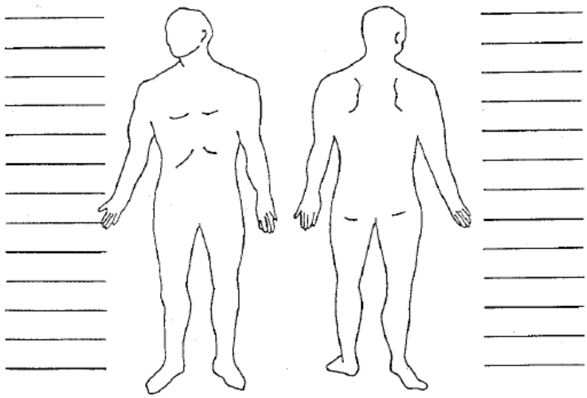
Address: ____

Date of measurement:_____/_____/_____ Time of measurement:__________

Contamination survey

Instrument type: ________________ Model: __________

Background reading: ____________ Detector active surface: ____________ [cm²]



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. 25. Sample of a worksheet for radioactive contamination control of a person involved in a radiation emergency [4].

III.3. WORK SHEET 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

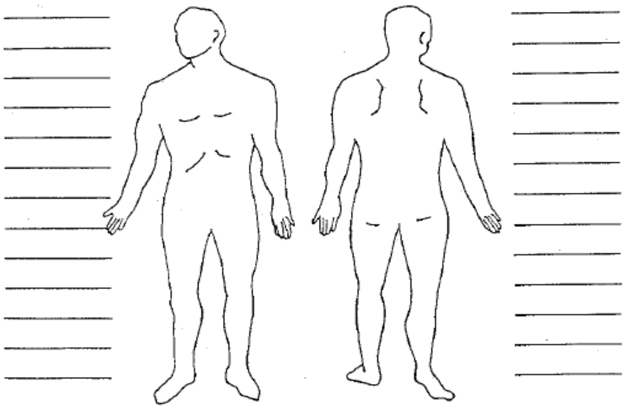
Name of victim: ______________________________ Sex: ☐ M ☐ F

Date of measurement:_____/_____/_____ Time of measurement:___________

Contamination survey

Instrument type: __________________ Model: ___________

Background reading: _____________ Detector active surface: ____________ [cm²]



Remarks: Indicate readings in the lines provided in the diagram. Indicate location of the readings by arrows. Only record readings greater than background.

Results of thyroid survey:________________[ ] ________________ [ ]
(count rate from neck) [Unit] (count rate from thigh) [Unit]
________________ [ ] ________________ [ ]
(background count rate) [Unit] (net count rate) [Unit]

Calibration coefficient:_________ [Bq/Unit of count rate] Activity_____ [Bq]

Further evaluation at medical facility necessary: ☐ Yes ☐ No

Surveyor signature: ________________

FIG. 26. Sample of a worksheet for recording radioactive contamination surveys of a person involved in a radiation emergency [4].

III.4. WORKSHEET 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. 27. Sample of a worksheet for recording the results of dose assessment for a person involved in a radiation emergency [4].

III.5. MEDICAL FOLLOW-UP

TABLE 28. IDENTIFYING INDIVIDUALS FOR MEDICAL FOLLOW-UP [32].

Who	**Comments**
Those within the precautionary acting zone (PAZ) and urgent protective action planning zone (UPZ) during or following release.	Information should be provided on their location and activities during the emergency. The skin and thyroid should also be monitored.
Those in areas where OIL1 or OIL2 were exceeded.	
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 medical follow-up.
Those with a dose rate from the thyroid exceeding OIL8.	Monitoring of the thyroid and skin should be performed after 1 d and before 6 d post-exposure.
Those who may have consumed contaminated food, milk or water with concentrations exceeding OIL7.	

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, should be registered and told that: (a) the risk to their foetus is small, but this can only be assessed by an expert on the health effects of radiation exposure (not their local physician); and (b) their risk will be evaluated, and an official will contact them to discuss the results and answer their questions.

To determine who needs to receive 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 should 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: Assessing food, milk and water radionuclide concentrations.
(d) OIL8: Assessing thyroid from radioactive iodine intake.

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ABBREVIATIONS

CDC	Centers for Disease Control and Prevention
EPD	electronic personal dosimeter
EPR	emergency preparedness and response
ICS	incident command system
MP	medical physicist
OIL	operational intervention level
OSL	optically stimulated luminescent
PPE	personal protective equipment
RA	radiological assessor
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.	National Atomic Energy Commission, 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

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INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA