TMT HANDBOOK

Triage, Monitoring and Treatment of people exposed to ionising radiation following a malevolent act

Carlos Rojas-Palma ▪ Astrid Liland ▪ Ane Næss Jerstad
George Etherington ▪ María del Rosario Pérez ▪ Tua Rahola ▪ Karen Smith (Eds.)

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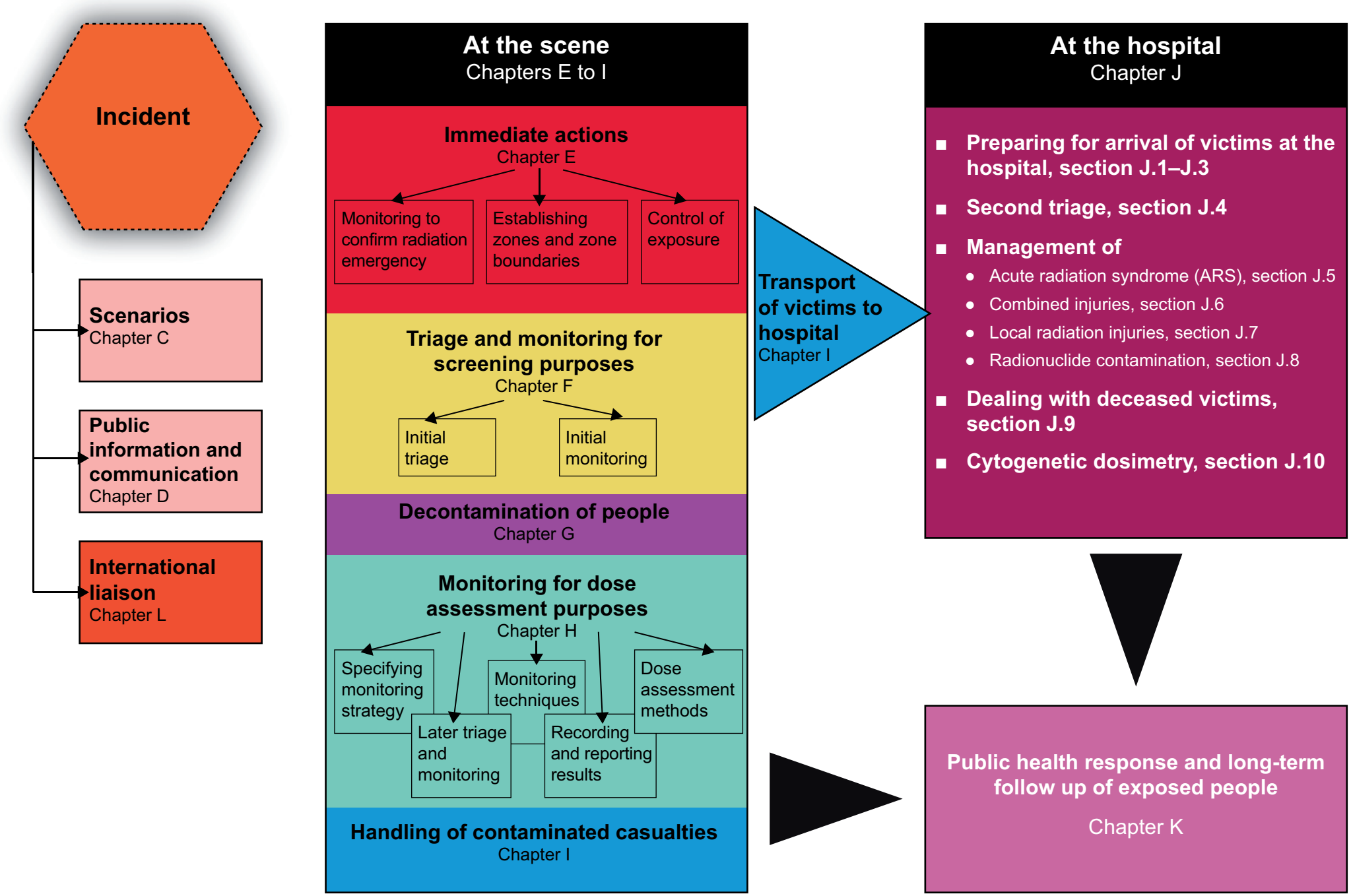
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Carlos Rojas-Palma, Astrid Liland, Ane Næss Jerstad, George Etherington, María del Rosario Pérez, Tua Rahola, Karen Smith (eds.) [2009]

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Foreword

European national emergency response plans have long been focused on accidents at nuclear power plants and other nuclear installations. Recently, possible threats by disaffected groups have shifted the focus to being prepared for malevolent use of ionising radiation aimed at creating disruption and panic in society. Although some countries may have adequate national plans for response, there is a need for European guidelines on how to act in the event of malevolent use of radioactive material.

This Handbook has been produced by the project TMT Handbook (Triage, monitoring and treatment – handbook for management of the public in the event of malevolent use of radiation) to address this need. The project has been partly funded by the European Commission under the 6th Euratom Framework Programme for Research and Technological Development under grant FI6R-036497. The coordinator of the project has been Carlos Rojas-Palma from SCK•CEN – Belgian Nuclear Research Centre.

More detailed information about the methodology applied for the development of Chapters J and K of this Handbook is provided in Annex 14.

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CHAPTER A

Introduction

Aim

This Handbook has been produced to address the need for practicable tools to assist those responding to malevolent use of ionising radiation. The Handbook is intended for the purpose of planning and training by emergency response organisations, and subsequent use in the field.

Audience

The Handbook is developed for use by emergency response organisations with specific functions to plan, coordinate and execute mitigating actions in response to incidents involving the malevolent use of ionising radiation. It gives guidance both for field operations and for medical treatment at the hospital, as well as public health response.

Although the Handbook gives specific instructions for actions at the scene and at the hospital, any user would need to be familiar with the Handbook content before responding to an actual event. The Handbook is thus not intended as a quick look-up guide for first responders with no prior knowledge or training in emergency situations involving ionising radiation. It can, however, be used for training of response personnel and experts in radiation protection or medical treatment, and as a tool in emergency exercises.

Handbook content

The Handbook content focuses on topics specifically related to the radiological triage, monitoring and treatment necessary to respond to a malevolent act, while ensuring the appropriate protection of responding personnel. The content builds on state-of-the-art procedures and techniques, and on relevant international guidelines. It contains both general information and detailed proposals for actions to be taken in the field and in the hospitals by specialised teams in radiation protection, monitoring and medical treatment. This information can be found in chapters E to J, which constitute the core content of the Handbook. Supporting information is given in the other chapters.

Chapter B gives an explanation on the Handbook structure and guidance on how to use it.

It is strongly recommended that users read Chapter B carefully before proceeding to Chapters E to J.

Chapter C gives a summary of possible malevolent scenarios.

Chapter D gives general guidelines on public information and communication strategies.

Chapter E describes immediate actions to be taken at the scene, including monitoring to confirm a radiation emergency, establishing zones and controlling exposures of people responding to the incident and members of the public.

Chapter F describes triage and monitoring for screening purposes in the field.

Chapter G gives information on decontamination procedures in the field and self-decontamination at home.

Chapter H gives advice on monitoring strategy, monitoring techniques, assessment of doses, and reporting monitoring results.

Chapter I concerns the handling of contaminated casualties and transport of patients to hospital.

Chapter J details actions to be taken at the hospital for proper handling of patients with local radiation injuries, acute radiation syndrome or combined injuries (conventional and radiation injuries). The management of contaminated patients is also addressed, including decorporation techniques for internal contamination.

Chapter K deals with public health response and long-term follow up of exposed people.

Chapter L is dedicated to international cooperation on early warning and assistance.

The annexes include supporting information on:

- Required facilities and equipment;
- Example forms, questionnaries and information leaflets;
- Allocation of roles;
- Interpretation of clinical signs and symptoms;
- Specifying a monitoring strategy for internal contamination;
- Later triage and monitoring, monitoring teqniques and biodosimetry;
- Action Levels;
- Sampling of excreta and blood;
- Management of internal contamination; and
- Assessment of internal doses.

A glossary is included for explanation of relevant terminology used in the Handbook. A list of acronyms and abbreviations used in the text is also provided.

The Handbook does not contain a general description of radioactivity, radiation protection nor instrumentation. This information may be found in many books in various languages across Europe. Nor does the Handbook contain descriptions of normal emergency actions in the field or at the hospital as first responders are already trained for such tasks. The Handbook provides instructions on actions specifically required for handling radiation incidents.

Although the focus of the Handbook is response to malevolent acts, the guidelines could also be used for response to other non-site specific incidents involving ionising radiation like orphan sources or accidents involving transport of radioactive material.

National adaptation

It is envisaged that this Handbook could help create a European standard for response to malevolent acts involving ionising radiation. At the same time it is acknowledged that the European countries are diverse with respect to size, capacities, organisational structure, regulations, climate and culture. For the implementation of these guidelines, end users should

consider national feasibility, availability of resources and capabilities, as well as country specific conditions. As a result of this, the guidelines may be adapted to national conditions and regulations. Nonetheless, it is anticipated that the Handbook will contribute to harmonisation across Europe concerning triage, monitoring and treatment of people exposed to ionising radiation following a malevolent act.

CHAPTER B

Handbook structure and how to use it

The structure of the Handbook is depicted in the fold-out page of the front cover. It follows the timing of various actions necessary to address a malevolent act, starting with defining the emergency zones, then triage, monitoring and on-scene treatment, followed by medical treatment in hospitals and long-term follow up of exposed persons. Public information and communication is expected to take place throughout the response phase, at various levels. The different chapters have been given a chapter specific colour coding. The colours are reflected in chapter titles in the fold-out figure in the front cover to make navigation easy.

The different chapters may be used independently by the reader. Hospital staff could for instance go directly to chapter J. There are, however, links between different chapters for consistency. Links to other parts of the Handbook are given in square brackets. Complementary information is given in annexes, and these are referenced as appropriate.

Instructions vs Information panels

Chapters E to J have a specific lay-out. On the left hand page, introductory parts are given in grey boxes followed by instructions on how to act in various situations. Each instruction has a unique number, starting with the chapter letter and then consecutive numbering within that chapter, e.g. E.1, F.11, G.24.

The right hand page gives supporting and additional information related to the instructions. The information panels have the same number as the instruction to which it refers. In some cases, the information panel relates to a whole section. This is then stated explicitly.

In chapters E to J both the sections and the instructions are given in the order in which the issues would be expected to arise. The necessary actions are thus listed chronologically and not grouped according to type of response team or type of incident.

Main chapter

Instructions on left hand page

Chapter F Triage and monitoring for the purpose of screening — Instructions

Type of incident

Indicates if the incident is of a covert or overt nature

F.10 **Covert external irradiation incidents**
(EXTERNAL IRRADIATION INCIDENTS) [COVERT]
(RADIOLOGICAL TRIAGE TEAM)
If the incident was covert (i.e. the location of the source was unannounced, or was unknown prior to detection), then it will not be possible to carry out Instruction F.9 fully until information is obtained on the locations of the source during the period that it could have resulted in irradiation of members of the public. Such information must be obtained from intelligence sources. Procedures for obtaining such information are beyond the scope of this Handbook.

Unique instruction numbering

Response team

F.11 **Target groups for triage, contamination incidents**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE TEAM)
The following groups of people must be identified and then subjected to triage based on information on location relative to the source

- People who are emerging from Red Zone set up around the source of contamination [Section E 3];
- People who believe they were within the Red Zone at any time since the incident, before or after the Safety Perimeter was set up
  - It will be necessary to define this area on a map so that streets and buildings can be identified; and

Figure B1 (both pages). Example of the chosen structure in chapters E to J.

Additional information on right hand page

Sub-chapter

Information — 2 Initial triage

Information F.10

Covert scenarios
In the absence of adequate information on source location, greater reliance must be placed on triage based on clinical signs and symptoms [Section F.2.2.2] and on biological dosimetry [Section J.10] to identify affected individuals. Effective communications to the public using radio, TV and newspapers will be needed. It must be accepted that it will not be possible to identify everyone whose health may be affected by the incident.

Link to another relevant section

Additional information relating to Instruction F.11

Information F.11a

Effect of wind direction
Wind direction should not be used in the selection of people for this stage of triage. In an urban environment, wind direction is not a good indicator of potential exposure. Exposures seemingly upwind can be greater than downwind at the same distance from the source because of the complex airflow patterns around buildings.

Types of incidents

The Handbook considers three types of incidents (or a combination of these):

- Environmental contamination incident;
- Food/water contamination incident; and
- External irradiation incident.

In those cases where the instructions are relevant only for specific types of incidents, this is stated at the beginning of the actual instructions or at the beginning of the section. If no indication of incident is given, the instructions are relevant for all incidents. The incidents could be of a covert or overt nature. Covert means e.g. secret/hidden source or unannounced contamination, while an observable source or an announced contamination would be of an overt nature.

Response teams

Various response teams are necessary to perform the different instructions given in this Handbook. The proposed teams are stated in Table B1.

Table B1: Response teams

At the scene	At the hospital
Tactical Incident Command (TIC)	Security Personnel
First Responders	Ambulance Team
Security personnel	Emergency Medical Manager
Medical Team	Hospital Emergency Team
Environmental Monitoring Team	Pathology Department
Radiological Triage Team	**Radiation Protection Officer**
Decontamination Team	**Health/Medical Physicist**
People Monitoring Team	
Dose Assessment Team	
Records Team	
Ambulance Team	

The teams given in bold are teams specifically designed to respond to radiological incidents, while the others are teams normally involved in any incident/accident where people would need assistance at the scene or at a hospital. In the heading of each instruction the relevant teams for performing the actions are given in brackets. A figure of the different teams necessary at the scene of a radiological incident is given at the fold-out page of the back cover. The colour coding corresponds to the chapters where the main tasks of these teams are described.

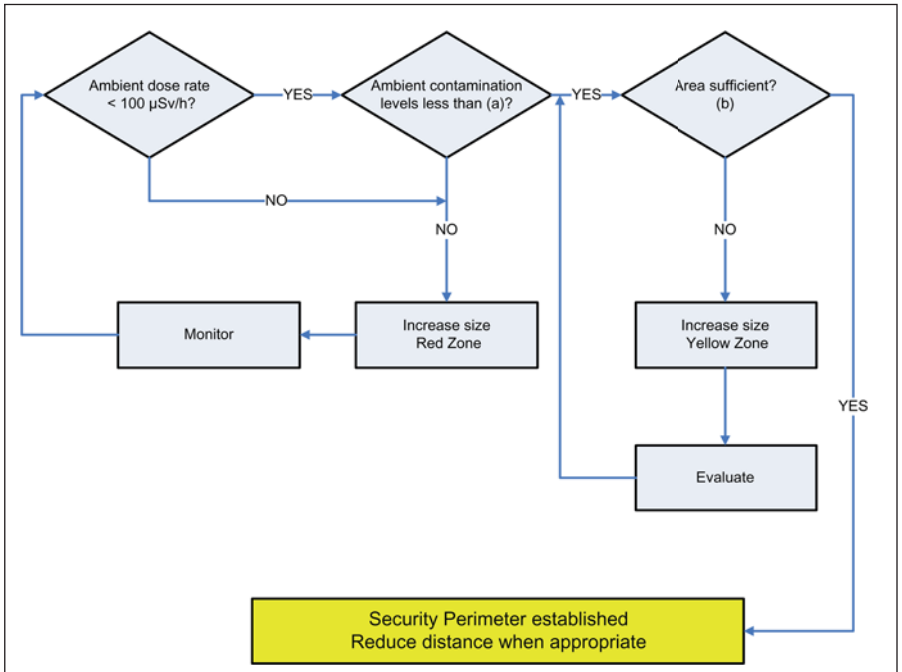
Further description of the roles and responsibilities of various teams is given in Annex 4.

Flowcharts

The Handbook contains various flowcharts for decision support. One example is given in Figure B2.

The rhombuses indicate that a decision has to be made, while the rectangles indicate actions to be taken. Rectangles with dotted lines refer to another flowchart.

The flowcharts presented are generic ones and might need to be adapted according to the real event. Example of such an adaptation related to a specific exercise scenario, is given in Information F.38b.



(a) 1000 Bq/cm² beta, gamma or 100 Bq/cm² alpha
(b) For requirements of emergency services AND access through Security Perimeter can be controlled effectively

Figure B2. Example of a flowchart

CHAPTER C

Scenarios

1 Introduction

The scenarios described here are used for illustrative purposes only. They are not meant to indicate the probability or possibility of any such event actually occurring. Neither should it be assumed that the scenarios described here are an exhaustive list of the possible incidents that could occur. Predictions of what might actually happen based on the scenarios considered in this handbook are at most semi-quantitative, since reality differs from human imagination. The poisoning of Alexander Litvinenko with ^{210}Po in 2006 serves as an example of this, since prior to the event such a scenario was not considered in emergency and response plans.

2 Considered scenarios

The aim of malevolent acts with radioactive material is to induce a significant economic, political and/or health effect, including psychological stress. The casualties in such incidents are likely to be members of the public. According to event, the number of affected people could vary from a few to mass casualties (i.e. a high number of exposed and/or injured people). Some scenarios could result in received doses high enough to cause Acute Radiation Syndrome (ARS). For other scenarios, such exposures are unlikely. Radiation injuries could also be combined with conventional injuries. A number of potential scenarios for such events are possible to identify. Possible scenarios include:

- Radiological Exposure Device;
- Radiological Dispersal Device;
- Attack on transport of radioactive material;
- Contamination of food and water supplies;
- Attack on nuclear installation or installation containing radioactive material; and
- Improvised Nuclear Device.

The two latter scenarios have not been elaborated further. An attack on a nuclear installation and subsequent release of radioactive material is well covered by the existing emergency plans. An attack on an installation with radioactive material (e.g. sources in medicine or industry) would be covered by the description of a Radiological Dispersal Device, while an attack with an Improvised Nuclear Device (home made nuclear weapon) is beyond the scope of this project.

2.1 Radiological Exposure Device

A Radiological Exposure Device (RED) is a hidden radioactive source that will typically irradiate people externally. Internal contamination could occur if the source is compromised either deliberately or accidentally.

If the objective is to affect the maximum number of people the RED is likely to be placed where a large number of people would be present, congregate or pass by. It could be moved to different locations for this purpose. An alternative would be the targeting of specific individuals, or high-level authorities.

2.2 Radiological Dispersal Device

A Radiological Dispersal Device (RDD) is a device for spreading radioactive material to contaminate a large area and/or number of people. The spread of the radioactive material can be performed by an explosive, also called a “dirty bomb”, but other means may also be used for dispersion. The event could be of a covert or overt nature.

The effects of radiological contamination dispersed by an explosion are difficult to predict and depend on diverse factors like environmental conditions (temperature, time of day, relative humidity, wind conditions, precipitation), chemical and physical form of the radioisotope (particle size, etc), type and amount of explosives, local environment, etc. Calculations serve at their best therefore as a semi-quantitative approximation of the potential situation and resulting contamination. Reality will in all probability differ from any modelled simulations.

2.3 Attack on transport of radioactive material

Transport of radioactive material may contain a very high amount of radioactivity. An attack may have the purpose to spread the radioactive material in the immediate neighbourhood of the scene or to transport the material to another place where a release of the radioactive material can do significant harm to society. The variety of material transported means that it is difficult to predict the consequences. The material could be used in RED, RDD or to contaminate food and water supplies.

2.4 Contamination of food and water supplies

The contamination of food or water supplies may have a direct impact on public health. The contamination can be performed in an indirect way via contamination of a lower part of the food chain, like cattle food or water, or more directly via contamination of human food, e.g in the food industry. Water can be contaminated in drinking water reservoirs or closer to the tap points, e.g. at the distribution points of local neighbourhoods.

CHAPTER D

Public information and communication strategy

1 Introduction

The scenarios described in the previous chapter all present tremendous challenges to public communication efforts. In the following section, some general ideas and recommendations are presented. However, it must be recognised that there exist cultural differences between countries, and therefore similar means and techniques for communication may not be effective in all countries. Any approach would need to be tailored to the specific situation and location.

Public communication should be considered a key function in any response involving the malevolent use of radiation. Without successful public communication, authorities cannot achieve their emergency response objectives to save human lives and protect the public and the environment. Thus, information strategies constitute an integral part of emergency preparedness. Authorities, be it on a national, regional or local level, should prepare to respond to the public information demands that will arise during an event involving the malevolent use of radiation. To be effective, a public information response should be planned in advance of any emergency. These plans will need to be integrated within the overall planning for managing malevolent acts and should detail the roles and responsibilities to be carried out during the response.

2 Public communication as an emergency response tool

Public communication activities can help prevent unnecessary fear or panic. In general, the public has little knowledge of radiation. This can be attributed to a number of factors. This field of expertise is not readily accessible to the layman. At the same time, however, the effects of, for example, nuclear accidents are well known. The Chernobyl accident in 1986 is still well remembered. The Litvinenko case in London in 2006, involving the use of ^{210}Po, shows how most people are dependent on statements made by experts or the information communicated through the media. And the media works fast! It is not uncommon, during events or accidents, to find the media to be the first on the scene. This implies that the public interpretation of the crisis is created at the same time as the emergency preparedness response efforts unfold.

To an ever increasing degree, the public can monitor how an emergency or crisis evolves, in real time, on live TV or on the internet. Hence, the emergency response organisation must realise, and act upon, the fact that the media created impressions of a crisis are as real as the crisis itself. Risk communication needs to consider the difference between how a risk is perceived by the public versus how the risk is actually assessed and measured by the experts. Effective risk communication may not be able to change strongly held perceptions, but it can improve understanding of, and compliance with, response measures.

For a member of the public, first and foremost it is important to establish whether or not the risk at hand constitutes a danger to themselves or their loved ones. Secondly, they need to be able to make their own informed decisions on what actions to take. In case of an event involving the malevolent use of radiation, both the scenario and the motive will influence on risk perception. A person's experience, attitudes and knowledge will also influence on how risk is perceived. The less knowledgeable a person is about a risk, the more the person is likely to rely on information provided through the media.

So, if emergency response organisations can provide relevant acurate information on the risk and response measures, in a prompt and timely fashion, then there is a good chance of meeting the needs of the target group, and subsequently, providing effective crisis communication. Basically, this means providing information on what has happened, the consequences thereof, and the response measures (to be) implemented. Moreover, information on response measures should also be clearly separated from other information being released. If that information is not delivered on time, or clearly phrased, it may result in a lack of trust in the response organisation. Independent, authorative guidance will be seen as the best source of information.

3 Effective public information – some key elements

For public communication to be credible and trustworthy, the organisation providing it must be seen as open and transparent. The need for transparency may be difficult to comply with since the information available is usually incomplete due to the time necessary to fully understand what has happened. However, lack of information may be interpreted as trying to hide something from the public, which in turn will impact negatively on the emergency response organisation's credibility. Timely information is thus of the essence, and it is important to keep a low threshold for handing out information to the media. To wait until there is a comprehensive and verified picture of what has taken place before releasing information to the media (and the public) could result in the media preferring other, less authoritative sources of information. In the first hour(s), lacking verified information to hand out, the emergency response organisation can at least inform about what their responsibilities are and what is being done, until more information is available. Doing so will help establish the emergency response organisation as a credible source towards the media, and show the public who is in charge. The media is in fact a very well suited platform for disseminating crucial messages, and should be regarded by the emergency response organisation as an additional resource.

A plain language explanation of the radiation risks and any countermeasures being taken is a vital part of an effective risk communication process. It not only facilitates public understanding, it satisfies their need for information and fosters trust with those who are in charge. Trust and availability of information become the key elements for risk communication. To establish this trust, particularly during emergencies where the public may be asked to comply with countermeasures, information provided to the public must not only satisfy their needs, but must also be provided in plain language so that it can be easily understood and facilitate their decision making.

It is recommended that all updates, news or (monitoring) results are published on the internet as soon as they come in, and not withheld from the media, unless obstructive to the police/intelligence investigations. Care also needs to be taken when dealing with medical-in-confidence data. How this data is managed needs to be considered as part of the communication strategy. It may also be a good idea to have only selected spokespersons making statements to the media as it will most likely facilitate coordination both within and between different organisations.

Events involving the malevolent use of radiation will be followed closely in neighbouring countries, or even worldwide. Hence, the media pressure may become overwhelming. Also, the general public will demand timely and complete information on the risks and prognosis during such an event. Advances in information communication technology and the globalisation of the news media have increased the demand for real-time information about any incident or emergency. The media is generally considered as the primary source of information to the public, although the internet is gaining in importance in providing information and should be utilised to its full extent.

By definition, an event involving the malevolent use of radiation is an unexpected one and there is very little or no time available before the first media or public inquiry is received. At this point the ability for the emergency response organisation to provide clear, if not precise, information on what is known at the time is a key element.

4 Plan ahead

Some information products can, at least partly, be developed in advance of an emergency. These products can be developed for a variety of target audiences depending on the potential emergency situation and information needs. By developing information products in advance, they can be rapidly distributed or adapted as necessary in the event of an emergency. To develop templates of required products such as press releases; questions and answers format information; basic advice on general actions the public can take; general background information on radioactive materials; contact information, will save time when dealing with an actual emergency situation. Some example templates are provided in Annex 3.

Other information products will need to be developed in response to the specifics of the situation. This information is produced according to the situation and how it develops, what response measures are chosen as well as what protective actions and advice to the public is initiated by the response organisation. Information products (press releases, press conferences, media statements, website updates, monitoring results, etc.)

are generated with some degree of uncertainty as to how the situation might evolve. However, it is important to maintain the information effort with frequent updates. The media is always very quick to react and to make use of the first information obtained, from any source. Any delay in providing clear (and verified) information to the mass media and the public creates an atmosphere for spreading rumours and information without evidence. These may be very difficult to correct later on since they may be more emotional than rational.

5 Coordination and consistency

Proper coordination between governmental and official bodies that are likely to interact with the public is crucial for effective public communication. Any lack of coordination may result in critical inconsistencies between various official sources of information, which again would have a negative impact of public trust towards these official bodies. National level plans and procedures should be in place to coordinate public information activities with regional and local authorities. It is vital to the credibility of the response that the information itself be consistent. Procedures should identify roles and responsibilities of the different actors in the public information response of the organisations and should include specific mechanisms for coordination of information between all levels. Procedures should also be developed for the wide variety of public information activities – media monitoring, media relations, public information products, public hot-line for questions – that may be needed during an emergency response.

6 Instructions – public communication in the event of malevolent use of radiation

Public communication must be:

- Transparent and open;
- Prompt, avoid unnecessary delays;
- Frequent;
- Reliable – never lie;
- Objective;
- Understandable to the layman, use plain language;
- Two-ways; and
- Not obstructive to police/intelligence investigations

In crisis communication it is important to:

- Define key messages;
- Establish target audiences, and tailor the information accordingly;
- Show empathy with the casualties and their next of kin; and
- Select appropriate modes of communication.

In providing service to the media it is useful to note that:

- Selected personnel should be available to the media at all times; and
- It will ease off some of the media pressure on the response organisation/ spokespersons if you spend time on:
  - Regular press releases;
  - Press conferences – at regular, set intervals, if possible; and
  - Internet. Suggested web content includes:
    - Press releases and public statements
    - Background information, fact sheets
    - Questions and answers
    - Results of monitoring
    - Links to other related sites.

The following tasks should always be planned ahead:

- National, regional and local public information plans/procedures must be in place defining roles and responsibilities, necessary resources and manpower;
- In order to avoid contradictory messages, plans on how to coordinate public information between different national authorities must be in place;
- Develop a task list for all personnel – a “what to do” in case of an emergency;
- Crisis management is exhausting – have a pre-planned roster of staff, including trained spokespersons;
- Templates for press releases, protective directives etc. and their dissemination capabilities; and
- Plain language conversion of scientific/technical information.

The following could also be valuable if resources are available:

- Media monitoring and analysis;
- Draft fact sheets, draft Questions & Answers;
- Toll free number for public calls; and
- Logistics and procedures to establish a dedicated public information centre.

Last, but not least, it is essential to carry out exercises, preferably including media professionals. The exercises must be evaluated and the lessons learned taken forward to improve the information and communication response.

CHAPTER E

Immediate actions

Introduction

In the initial stages of the response, there will be little time to carry out detailed planning of the response, and minimal information on which to base such plans. Chapters E, F and G describe initial actions to be taken at the scene (mainly during the first 48 hours after notification or discovery of an incident). These actions may be implemented automatically without the need to develop plans that are specific to the incident. Recommendations for developing a detailed plan for monitoring after the initial (emergency) phase are given in Section H.2.

1 Control of exposure

Introduction

The purpose of this section of the Handbook is to give instructions on how to control the exposure to ionising radiation at the scene.

Instructions are directed to:

- First responders working at the scene in the first moments after the incident;
- Authorised personnel who are not emergency workers; and
- Tactical Incident Command (TIC) for protection of the public.

Information E.1

Figure E1. Examples of the personal protective equipment. Left: waterproof clothes and full face respirator. Right: Disposable coveralls and dust mast. Photos: STUK.

The guidance is given at the levels of dose that will allow completion of tasks and return to the base without exceeding the levels in the international guidance (IAEA Safety standards series GS-R-2, 2002, ICRP Publication 96, 2005). Emergency dose guidance levels for workers are expressed as integrated external dose. It is assumed that all necessary precautions are taken to prevent internal exposure. The guidance is for the entire emergency period. National regulations may result in more restrictive dose constraints, which should be followed.

Instructions given in this section should always be applied when responding to a radiological emergency unless directed otherwise by the TIC.

1.1 First responders

CAUTION: Only first responders wearing waterproof protective clothing and full face respirators should do life saving actions and evacuation before the radiological assessment at the scene has been made. Female workers who may be pregnant should notify the appropriate authority and must be excluded from emergency duties.

E.1 Instructions that should always be followed

(FIRST RESPONDERS)

1. Follow standard safety procedures for your professional area.
2. Wear some form of identification (high visibility uniform, armbands, jacket etc.) when within the Red Zone.
3. Do not touch/hold suspected radioactive items, including bomb fragments (shrapnel).
4. Perform only the following actions within 1 metre of suspected radioactive materials/source or, within 100 metres of fire or explosion:
   - Life saving actions;
   - Actions to prevent the development of catastrophic conditions; and/or
   - Actions to prevent severe health effects or injuries (e.g. evacuation/protection of the public, rescue from potential threats of serious injuries, immediate treatment of serious injuries).

Information E.1 (cont.)

Occupational protection techniques

Managing field exposures

The dose rate may vary considerably over short distances. As there is unlikely to be an experienced radiation protection professional at hand, and dose levels will not usually be clear until later in the event, first responders need to have a method to assess their individual exposure to external radiation during the initial stages of the event [Annex 8]. First responders should, therefore, be issued alarming detection devices that will indicate when certain dose rates or total cumulative external doses have been reached. Noting that such devices will not detect non-penetrating radiation or hazardous levels of airborne radioactive material, first responders need to be made aware during training of these limitations.

Integrating alarming dosemeters should be provided to the responders, with appropriate alarms corresponding to the guidance levels in Table E2 [Information E.5]. For instance, the alarm levels should warn first responders when their doses approach levels of 5, 50, and 500 mSv. Alarming dose meters do not measure the dose from inhalation, ingestion or skin contamination. Responders must also follow all the general instructions in Section E.1.1 to limit the dose from these pathways. The dose meter alarm levels should be reviewed throughout the response and lowered when appropriate.

Following the detonation of an RDD or release from RDD, the radiation fields in the immediate vicinity may be extremely inhomogeneous due to the presence of highly radioactive fragments – resulting in radiation *hot spots*. People managing field exposures need to be aware of this possibility, especially if the parameter "time" is used as the only variable to manage the doses to first responders.

Personal Protective Equipment (PPE)

Protective clothing

The skin should be protected to reduce potential burns from high levels of relatively non-penetrating beta or alpha radiation, and to prevent possible transfer of radioactive material into the body through the skin and inadvertently through the mouth or nose. The choice of clothing will often be influenced by more immediate hazards such as fire, heat, or chemicals. Protection against these other hazards will generally provide protection from radioactive material. For medical personnel, normal barrier clothing and gloves may provide personal protection against intake of contamination. Disposable medical scrub suits, high-density polyethylene or other close-weave coveralls, safety helmets and waterproof shoes or boots should be used if available. Secondary contamination of the medical staff from handling patients should not be a cause of great concern. However, to prevent the unnecessary spread of contamination and thereby reduce the need for clean up, it is prudent to utilise conventional protective clothing. (Continued over page)

5. Minimize time spent within 10 metres of suspected radioactive materials/source.
6. When dispersion of radioactive material (dust/smoke) and contamination are suspected or confirmed:
   - Use protective clothing and respiratory protection equipment; and
   - Keep hands away from mouth, do not smoke, eat or drink and wash hands regularly.
7. When treating or transporting contaminated persons use normal barrier methods (standard precautions) such as protective clothing, surgical gloves and masks. Keep hands away from mouth and wash hands regularly.
8. Take a stable iodine tablet if instructed to do so by your field controller/supervisor [Instruction J.24]. Record the fact that you have taken a tablet [Form A3.5, Annex 3].

E.2 Limiting exposure for emergency workers

(TACTICAL INCIDENT COMMAND [TIC])

1. Ensure that the names and occupancy times of the first responders and activities performed by them are recorded when they are within the Red Zone – for possible follow up and dose reconstruction [Annex 3].
2. Instruct the first responders to get monitored for radioactive contamination after being within Red Zone [Section F.3.3]. If not immediately possible, advice them to shower and change clothing as soon as possible [Chapter G].
3. As soon as possible have work areas monitored [Section F.3.2].

E.3 Instructions if gamma dose rate is known

(FIRST RESPONDERS)

1. Follow Instruction E.1 above.
2. If ambient dose rate in a particular area is greater than 100 mSv/h perform only the following actions:
   - Life saving actions;
   - Actions to prevent the development of catastrophic conditions; and
   - Actions to prevent severe health effects or injuries (e.g. evacuation/protection of the public, rescue from potential

Information E.1 (cont.)

Respiratory protection

In most situations, respiratory protection that is designed to protect responders against chemical or biological agents is likely to offer adequate respiratory protection in a radiological attack. Concerns about the presence of chemical or biological contaminants will influence the selection of respiratory protection. If used properly, simple surgical facemasks provide reasonably good protection against the inhalation of particulates, and allow sufficient air transfer for working at high breathing rates. If available, high-efficiency particulate air filter masks provide better protection [Annex 8].

Personal Protective Equipment (PPE) appropriate to the role of the responder

In all cases alternative PPE giving a similar level of protection may be used.

A. First Responders and emergency workers entering the Red Zone:

- Full face respirator;
- Waterproof gloves (must be abrasion resistant)
- Waterproof clothing (all skin and hair must be covered)
- Waterproof shoes or boots;
- Safety helmet;
- Alarming personal dosemeter (measuring instantaneous dose rate as well as cumulative dose);
- A personal dosemeter (film badge or thermoluminescent dosemeter (TLD); and
- High visibility clothing is recommended.

B. First Responders and emergency workers entering the Yellow Zone and medical staff handling contaminated casualties:

- Surgical gloves, which should be changed frequently;
- Coveralls;
- Simple respirators/dust masks;
- Plastic shoe covers;
- Hair cover (e.g. surgical cap); and
- A personal dosemeter (film badge or thermoluminescent dosemeter (TLD) is recommended).

C. Personnel carrying out decontamination of people

- See B above
- Waterproof clothing is recommended.

threats of serious injuries, immediate treatment of serious injuries).

3. Do not proceed into area with an ambient dose rate of greater than 1000 mSv/h unless directed by TIC for life saving actions. Workers who undertake actions in the areas where the dose rate may exceed the limit shall be volunteers and must be clearly and comprehensively informed in advance of the associated health risk to allow them to make an informed decision.

E.4 Limiting exposure if gamma dose rate is known

(TIC)

1. Follow Instruction E.2 above.
2. Estimate the doses for the first responders using the recorded occupancy times and dose rates [Annex 3]. Limit their total time of staying in Red Zone so that the constraint of 50 mSv will not be exceeded [Table E1 in Information E.4, Table E2 in Information E.5].
3. The constraint of 50 mSv can be exceeded, if the first responders are needed to perform life saving actions or actions to prevent severe health effects/injuries or the development of catastrophic conditions [Table E2]. The workers shall be volunteers and must be clearly and comprehensively informed, in advance, of the potential consequences of the exposure to allow them to make an informed decision.

E.5 Guidelines if self-reading dosemeters are being used

(FIRST RESPONDERS)

CAUTION: Self-reading dosemeters do not measure the dose from inhalation, ingestion or skin contamination; consequently responders must also follow all the general instructions in Section E.1.1 to limit the dose from these pathways.

1. Follow Instruction E.1 and Instruction E.3 above.
2. Make all reasonable efforts not to exceed the dose guidance from the Table E2 in Information E.5.

Information E.4

Table E1. Examples of occupancy times in the areas with elevated dose rates.

Dose rate	Total time of staying after which the dose limit of 50 mSv will be exceeded	Total time of staying after which the dose limit of 500 mSv will be exceeded
0.1 mSv/h (100 µSv/h)	500 hours	5000 hours
1 mSv/h	50 hours	500 hours
10 mSv/h	5 hours	50 hours
100 mSv/h	30 minutes	5 hours
1000 mSv/h	3 minutes	30 minutes

1.2 Authorised personnel

E.6 Mandatory instructions for authorised personnel within the Red or Yellow Zones

(ALL TEAMS)

CAUTION: Female workers who may be pregnant should notify the appropriate authority and must be excluded from duties in the Red or Yellow Zone.

1. Follow standard safety procedures for your professional area.
2. Wear some form of identification (high visibility uniform, armbands, jacket etc.) when within the Red and Yellow Zones.
3. Use self-reading dosemeters given at the scene by radiation protection personnel.
4. Make all reasonable efforts not to exceed the dose guidance of 50 mSv for occupational exposure [Table E2].
5. If working within the Red Zone follow the instructions given in the Secure Access Control Point [Instruction E.36].
6. When treating or transporting contaminated persons use normal barrier methods as directed in Information E.1. Keep hands away from mouth and wash hands regularly.
7. Take a stable iodine tablet if instructed to do so by your field controller/supervisor [Instruction J.24]. Record the fact that you have taken a tablet [Forms A3.5 and A3.9, Annex 3].

E.7 Exposure records

(ALL TEAM LEADERS)

Ensure that the names and occupancy times of the team members and activities performed by them when they are within the Red or Yellow Zone are recorded – for possible follow up and dose reconstruction.

1.3 Public

E.8 Members of the public within the Red Zone

(TIC)

1. Evacuate as soon as possible [Table E3, Table E4]. Before

Information E.5

Table E2. Emergency worker turn back dose guidance. Reproduced courtesy of IAEA (IAEA EPR-First responders, 2006).

Tasks	Do not exceed unless approved by the incident commander, Hp (10)
Life saving actions, such as: - rescue from immediate threats to life; - provision of first aid for life threatening injuries; - prevention/mitigation of conditions that could be life threatening.	1000 mSv[1,2, 3, 4]
Actions to prevent severe health effects or injuries, such as: - evacuation/protection of the public; - environmental monitoring of populated areas to identify where evacuation, sheltering or food restriction are warranted; - rescue from potential threats of serious injury; - immediate treatment of serious injuries; - urgent decontamination of people. **Actions to prevent the development of catastrophic conditions, such as:** - prevention or mitigation of fires, etc; - apprehension of terrorist suspects.	500 mSv[1, 3, 4]
Actions to avert a large collective dose, such as: - environmental sample collection and analysis for environmental monitoring of populated areas; - localized decontamination if required to protect the public.	50 mSv[1]

**

1) This dose guidance is set at the levels that will allow completion of tasks and return to the base without exceeding the levels in the international guidance (IAEA Safety Standards Series No. GS-R-2, 2002). Emergency worker dose level guidance values are expressed as integrated external dose and it is assumed that all necessary precautions are taken to prevent internal exposure. The guidance is for the entire time of the emergency.
2) In principle, no dose restrictions are recommended for life saving if, and ONLY IF, the benefit to others clearly is more important than rescuer's own risk.
3) Workers shall be volunteers and be provided with information on the potential health consequences of exposure to allow them to make an informed decision (IAEA Safety Standards Series No. GS-R-2, 2002, IAEA Safety Series No. 115, 1996). For example: 3000 mSv exposure could be life threatening, 500-1000 mSv can result in short term vomiting, reduction in sperm count and an increase in the chance (risk) of development of fatal cancer from the normal rate of about 25 % to about 30 %. Exposure to a dose of 100 mSv will not result in any short term effects, but will result in a small increase (about 0.5 %) for the risk of development of fatal cancer (IAEA TECDOC 1432, 2005, ICRP Publication 96, 2005).
4) Every effort should be made to keep doses below this level while performing life saving actions.

evacuation takes place instruct the public to take best available shelter (e.g. go to indoor hall, stay away from windows).

2. Instruct them not to handle, but to isolate and identify to a responder, any possible radioactive item.
3. Instruct them not to smoke, eat, drink or place hands near mouth.
4. Following evacuation:
   (a) Register evacuated people [Annex 3];
   (b) If contamination is a concern (possible presence of radioactive smoke, liquid or dust):
      - Remind evacuees not to smoke, eat, drink or place hands near mouth
      - Perform monitoring [Section F.3.3]
      - If warranted and practical, conduct immediate decontamination [Chapter G];
   (c) Provide them with instructions on where to go for further information and/or medical/radiological assessment; and
   (d) Instruct them of the need, after leaving the scene, to:
      - Conduct decontamination at home (if not implemented at the scene) [Section G.3]
      - Listen for further instructions on where to get information and/or medical/radiological assessment.

E.9 Members of the public who may have left the Red Zone

(TIC)

Instruct them, if necessary via the media, on the following:

1. Not to handle any items, but report to the local police any items they might have picked up at the scene.
2. Not to smoke, eat, drink or place hands near the mouth until a shower is taken and clothes are changed.
3. To remove outer wear before entering home. Shower with warm water and mild soap. Change clothes, seal clothes in plastic bag and store [Section G.3].
4. To continue to listen for and follow official instructions given via the media (TV or radio).

Information E.6

Stable iodine

National arrangements for distribution and use of stable iodine for the purpose of blocking uptake of radioiodine to the thyriod should be followed. In the absence of national guidelines, the generic criteria for thyroid blocking recommended in IAEA EPR-Medical, 2005, should be adopted.

Information E.8

Table E3. Operational intervention levels (OILs) in radiological emergencies based on ambient dose rate measurements from gamma-emitting radionuclides.
Table adapted from IAEA TECDOC 1162, 2000.

Major exposure conditions	OIL	Main actions
External radiation from a point source	100 μSv/h	Isolate the area Recommend evacuation of Red Zone Control access and egress
External radiation from ground contamination over a small area or in the case of not very disruptive evacuation	100 μSv/h	Isolate the area Recommend evacuation of Red Zone Control access and egress
External radiation from ground contamination over a wide area or in the case of very disruptive evacuation	1 mSv/h	Recommend evacuation or substantial shelter
External radiation from air contamination with an unknown radionuclide(s)	1 μSv/h	Isolate the area (if possible) Recommend evacuation of Red Zone or downwind in case of open area

Table E4. Recommended avertable doses for undertaking countermeasures.
Table reproduced with kind permission from ICRP (ICRP Publication 96, 2005).

Countermeasure	Avertable dose (for which the counter-measure is generically optimised)
Sheltering	~ 10 mSv in 2 days (of effective dose)
Temporary evacuation	~ 50 mSv in 1 week (of effective dose)
Iodine prophylaxis (if radioiodine is present)	~ 100 mSv (of equivalent dose to the thyroid)
Relocation	~ 1000 mSv or ~ 100 mSv first year (of effective dose)

E.10 **Members of the public outside the Red Zone**

(TIC)

The members of the public outside the Red Zone should stay indoors and listen for official instructions given via the media (TV or radio). They should be advised not to go to the scene to volunteer to help.

If there has been an atmospheric release (smoke from fire or bomb) instruct public, via the media, within about 1 km of the release point that it would be prudent:

1. To remain inside building during the release (smoke).
2. Not to eat any vegetables grown outside or drink rainwater.
3. Not to play on the ground.
4. To wash hands before eating.
5. To avoid dusty areas or activities that will generate dust.
6. To listen for and follow official instructions given via the media (TV or radio).

1.4 Dealing with deceased persons

E.11 (CONTAMINATION INCIDENTS) (MEDICAL, AMUBLANCE, FIRST RESPONDERS AND ENVIRONMENTAL MONITORING TEAMS)

No special procedures need to be followed to handle people after external irradiation. Instructions below should be followed when dealing with human remains containing radioactive materials.

1. Apply radiation protection measures for managing deceased persons with external and/or internal contamination such as:
   (a) Use protective clothing and respiratory protection equipment; and
   (b) Place the contaminated corpses with clothing and personal effects intact in body bags, use appropriate labelling and visible radiation signs. Wipe the exterior of the bag with a small piece of absorbent paper and count the smears with a surface contamination monitor. Surveying the surface of the bag is not possible because the detector would register the radiation emanating from the interior of the bag.
2. Move the contaminated corpses to the temporary morgue established within the Yellow Zone.

For dealing with contaminated corpses at the hospital see Section J.9.

2 Monitoring to confirm a radiation emergency

Introduction

The purposes of this section of the Handbook are:

- To establish whether or not the incident involves the use of radiation or radioactive material [Figures E2a, E2b and E3];
- To establish whether radioactive material has been dispersed through the environment; and
- To establish approximately those areas where dose rates or levels of contamination are highest. (Dispersion may cause a spread of contamination so that several locations are of major concern).

The procedures in this section will facilitate collection of basic information about the scenario. This information is required for subsequent decisions about triage and monitoring [Section F.2.2].

Priorities and actions will differ according to the scenario. The following scenarios are considered:

- External irradiation incident;
- Environmental contamination incident; and
- Contamination of food/water.

These scenarios are associated with RED and RDD incidents in the following way:

1. RED is primarily an irradiation incident, but would in addition be classified as an environmental contamination incident if material was released from the irradiation source.
2. RDD is both an irradiation and environmental contamination incident.

Actions described in this section for an irradiation incident and environmental contamination incident are the same because:

- Until monitoring results are available it may be uncertain whether the incident involves irradiation only or irradiation combined with environmental contamination; and

Figure E2a. Basic ionising radiation warning symbol. Photo: HPA.

Figure E2b. Supplementary ionising radiation warning symbol. The symbol is intended for IAEA Category 1,2 and 3 sources defined as dangerous sources capable of death or serious injury. To be placed on the device housing the source, as a warning not to dismantle the device or to get any closer.

This symbol taken from ISO 21482:2007, Ionizing-radiation warning – Supplementary symbol, is reproduced with the permission of the International Organization for Standardization, ISO. This standard can be obtained from any ISO member and from the ISO Central Secretariat. Web site at the following address: www.iso.org. Copyright remains with ISO.

- An irradiation source may be damaged.

For an incident involving deliberate contamination of food or water, actions are very different and are described separately.

The required actions are described in the order in which they should be carried out.

E.12 Hazard Assessment

(TIC, FIRST RESPONDERS)

First responders must assume there is a radiological hazard, until a radiological assessment has been made. Signs that radiation may be present are shown in Information E.12b.

E.13 Establishing the scenario type

(TIC, ENVIRONMENTAL MONITORING TEAM)

1. Incidents may not involve environmental contamination; however, measurements must be carried out to confirm the absence of contamination, even if the incident involves a suspected irradiation device. It will not be possible to monitor close to an irradiation source until it is removed or shielded.
2. Monitoring for all radiation types (i.e. alpha, beta, gamma and neutron radiation) must be carried out and shown to be absent before the incident can be declared not to involve radiation or radioactive material.
3. Carrying out the procedures in this section will provide basic information about the scenario to be collected. This information is required for subsequent decisions about triage and monitoring [Section F.2.2].
4. Information on whether radiation or radioactive material has been used (or may be used) may be provided by means other than monitoring (for example, as a result of police intelligence or information from a terrorist organisation). Such information must be confirmed, by monitoring, and then may be used to adapt the procedures described in this section.

Information E.12a

When monitoring to confirm a radiation emergency, remember that accuracy of the measurement is not as critical as verifying that radiation is present. It is also important to determine the type of radiation present.

Information E.12b

Signs that radiation may be present:

- Spill, fire or explosion;
- Alarming personal dosemeter;
- Elevated reading on a dose rate meter;
- Elevated reading on a contamination monitor;
- Transport accident involving a vehicle with radiation warning labels;
- Presence of packages bearing the radiation symbol;
- Intelligence information;
- Information from witnesses; and/or
- People with symptoms consistent with radiation exposure.

Figure E3. Packages and vehicle with potentially dangerous sources symbol. Photos: HPA

5. If monitoring is carried out which confirms that the incident does not involve the use of radiation or radioactive material, then a statement that radiation is not involved should be passed immediately to *Strategic Command* [Annex 4]. Such an incident no longer falls within the scope of this Handbook.
6. Even if a radiation emergency has already been declared, ensure that all of the procedures described below for the relevant scenario have been carried out.

E.14 Establishing the tactical control point

(TIC, FIRST RESPONDERS, ENVIRONMENTAL MONITORING TEAM)

To manage the incident a "Tactical Control Point" (TCP) will need to be established [Section E.3.2]. The TCP must be set up as soon as there is notification of a potential or real emergency. The 'Tactical Incident Commander' (TIC) [Annex 4]has overall responsibility for the local incident response and will be located at the TCP. The TIC will need to initiate and direct radiation monitoring, and use the results to assess the situation.

E.15 Environmental contamination and external irradiation incidents vs. food/water contamination incidents

(TIC, ENVIRONMENTAL MONITORING TEAM)

For all incidents, with the exception of those involving contaminated food/water, the procedures in Instruction E.16 - E.22 must be followed. For incidents involving contaminated food/water the procedures in Instruction E.23 - E.24 should be followed.

2.1 Contamination and irradiation incidents

E.16 Monitoring teams

(TIC)

1. Monitoring teams should be established. These teams are likely be made up of staff from first responder organisations (e.g. fire service) or of specialist radiation protection staff [Annex 4]. It is unlikely that emergency services will have the equipment or experience to monitor for all types of radiation. Emergency services staff required to do emergency monitoring must, as a

Table E5. Guide to transport packages markings.

UN Number	Possible other marking	Threat
2909, 2908, 2910, 2911	None	**Not dangerous**
2912; 2913, 3321, 3322, 3324; 3325, 3326	Type IP-1, Type IP-2, Low Specific Activity (LSA), Surface Contaminated Object (SCO)	**Possibly dangerous** if material is inhaled or ingested
2915; 2982, 3327, 3332, 3333	Type A	**Possibly dangerous**
2916, 2917, 3328, 3329	Type B (U), Type B (M)	
3323, 3330	Type C	

Reproduced courtesy of IAEA (IAEA EPR-First responders, 2006; IAEA Safety standards series TS-G-1.2 (ST-3), 2002).

Figure E4. Typical radiography camera. Photo: HPA.

minimum, be able to identify elevated gamma dose rates. If only gamma dose rate monitoring is available then it must be assumed there is widespread contamination of the environment, until contamination monitoring has been carried out.

2. If at the early stages of the incident response, only equipment to measure gamma dose rate is available then equipment for alpha contamination, beta contamination and neutron dose rate monitoring must be urgently obtained.

E.17 Safety of monitoring team staff

(TIC, ENVIRONMENTAL MONITORING TEAM)

1. PPE (Personal Protective Equipment) must be worn, as described in Section E1.1.
2. Clear instructions are needed from the TIC about acceptable/unacceptable levels of exposure and permissible occupancy times [Section E1.1]. A warning must be given not to approach an irradiation source unless monitoring confirms that doses are within acceptable limits.

E.18 Equipment

(TIC, ENVIRONMENTAL MONITORING TEAM)

1. The following are essential equipment:
   (a) Two (or more) hand held monitors measuring gamma dose rate;
   (b) An alarming personal dosemeter (providing a measure of cumulative dose and an indication of instantaneous dose rate) for each person [Section E1.1]; and
   (c) Reliable 2-way communication with the control centre (Note that mobile phone networks may not be reliable [Information E.18:1c]).
2. The following equipment must be urgently obtained:
   (a) Alpha contamination monitors;
   (b) Beta contamination monitors;
   (An instrument capable of detecting both alpha and beta contamination could be used, but it must be able to distinguish between alpha and beta contamination.)
   (c) X-ray and low energy gamma contamination monitor;

Figure E5. Very dangerous source from radiography camera (should never be picked up). Photo: HPA.

Information E.18:1

Alarming personal dosemeters

The dose rate indication of these devices should only be used as a rough indicator of dose rate, as many have poor sensitivity due to long response times. The primary function is the measure of accumulated dose.

Information E.18:1c

Communication

In an emergency situation, the commercial GSM and GPRS-systems may collapse, as happened in the aftermath of the Tsunami in Thailand 2006, for example. Therefore it is important to have more than one communication channel between the mobile teams and the headquarters. The additional communication link may be a satellite phone capable of data transfer or a TETRA-based professional mobile radio.

In an emergency situation, the data transfer lines will be heavily loaded. Automation of data transfer must always respond to the following questions:

- What information should be transferred continuously, in real-time?
- What information should be transferred when certain decision criteria are met?
- How is additional data transferred?

The selection of data is crucial, since one cannot count on the normal available bandwidth in an emergency situation; therefore, it is wise not to push the transmission speed near to its extreme capacity.
(Continued over page)

(d) Hand held monitors for measuring neutron dose rate;
(e) Equipment to take wipe samples;
(f) GPS equipment;
(g) Detailed map of the area;
(h) Spray paint; and
(i) Means of recording information.

3. If available use a hand-held radionuclide identifier as means of determining the radionuclide(s) present. If this equipment is not available, or there is no significant gamma-ray emitting contamination, then take a wipe sample from a contaminated surface and arrange for this to taken to a suitably equipped laboratory as soon as possible. Inform the laboratory that the sample has been dispatched and instruct them to identify (but not quantify) the radionuclides(s) present as quickly as possible. Instructions for laboratory analysis are beyond the scope of this Handbook.

E.19 Locating areas with highest dose rate or contamination

(TIC, ENVIRONMENTAL MONITORING TEAM)

1. If present, the irradiation source and areas of highest contamination must be located. If dose rates are low enough, then a single team can achieve this. This is determined by estimating the cumulative dose and comparing with emergency worker turn-back guidance [Section E.1, Table E2]. If dose rates are higher then it may be necessary to send additional teams into the area from different starting points. It should not be necessary for all of the teams to enter areas of highest radiation, in order to achieve this. If the source of irradiation and/or the areas of highest contamination are not located then this must be a priority for later monitoring.
2. The TIC must keep records of the monitoring team's measurement so that it is clear when the irradiation source and/or the areas of highest contamination have been located. A form for recording measurements is included in Annex 3.

Information E.18:1c (cont.)

Data transfer should be highly automated. Crucial time is saved, when the position of the mobile teams is transferred automatically and in real time to a mapping system in the headquarters. When something is found, the location is already seen on the map and the communication between the mobile team and the headquarters can focus on what was found.

All functional data transmission pipelines needs well defined formats, protocols and send/receive procedures. These are defined by the data management of the system.

Information E.18:2

Monitoring instruments

The following is a comprehensive list of instrument types which may be useful for confirming the presence of specific radiation types or to identify the radionuclide(s) present:

- Alpha contamination monitors;
- Beta dose rate monitors;
- Beta contamination monitors;
- X-ray and low energy gamma contamination monitors;
- Gamma dose rate monitor;
- Portable gamma-spectrometry equipment; and
- Neutron dose rate monitor.

Annex 8 contains more detailed descriptions of these instruments.

Information E.18:2e

Surface monitoring using a wipe sample

The sampling location should be flat and smooth. The sample should be taken by wiping an area of approximately 100 cm^2. Light pressure should be used so that the wipe sample is not torn or rolled. Wipes may be taken from roads and pavements but only a small fraction of the total activity will be removed. Unless the exact fraction of non-fixed contamination by the wipe is known, a default value of 0.1 should be used. Use a portable contamination meter to assess activity on the wipe. The measurement must be done away from radiation sources. After monitoring the wipe sample should be placed in a labelled plastic bag with appropriate information about the sample, including sample location, date and time. Samples must be retained for laboratory analysis, this is particularly important for alpha emitters where self-absorption can lead to a gross underestimation of activity [Annex 11].

E.20 Post deployment actions

(TIC, ENVIRONMENTAL MONITORING TEAM, DECONTAMINATION TEAM)

After deployment, monitoring teams need to be monitored for contamination and, if necessary, decontaminated.

E.21 Detailed monitoring instructions

(ENVIRONMENTAL MONITORING TEAM)

1. Monitoring equipment must be tested before approaching the site.
   (a) Check condition of batteries before leaving your base of operations;
   (b) Check instrument response with calibration sources;
   (c) If more than one instrument is available perform cross checks to ensure a consistent reading;
   (d) Measure and record background readings from instruments;
   (e) After these checks leave all monitors switched on; and
   (f) Note cautionary advice in Information E.21.

2. Detailed monitoring procedure to be followed:
   (a) Start from TCP [Section E.3];
   (b) Approach at walking pace; continuously monitor gamma dose rate with an instrument that can read at least 100 mSv/h [Information E.21:2b]. If the dose rate is changing rapidly move more slowly;
   (c) Look for signs of a possible RDD or RED [Information E.21:2c];
   (d) Report results of measurements to TIC frequently (e.g. every 5 minutes); also report whenever gamma dose rate increases by a factor of 10 compared with previously reported value;
   (e) If gamma dose rate increases by a factor of 10 compared with previously reported value and if equipment is available carry out:
      - Alpha contamination measurements on “hard” upward-facing surfaces
      - Beta contamination measurements on “hard” upward-facing surfaces
      - X-ray/low energy gamma contamination measurements

Information E.21

Cautions for monitoring

Some instruments can saturate at very high radiation fields and show zero or low reading, or show ‘battery low’.

Monitoring teams need to be familiar with the monitoring instrument used and in particular be aware of requirements for probe to surface distance and rate of movement of the probe.

Monitoring instruments, with the exception of probes for alpha and beta contamination, should be covered with a plastic bag to facilitate decontamination.

Measurements of X-ray emitting radionuclide contamination and beta contamination should be made by taking a surface wipe sample and monitoring it away from any other sources of gamma and X-rays.

Alpha particles can not be detected with an instrument designed for beta/gamma radiation. Alpha emitting radionuclides often produce X-rays and photons, with a low abundance, which can be detected with beta/gamma sensitive instruments. The presence of alpha emitting radionuclides must be confirmed with an alpha sensitive instrument.

Alpha measurements can only be made on smooth surfaces which are free from water, oil, dirt etc. The probe must be held less than 1 cm from the surface being monitored.

Information E.21:2b

If gamma dose rate instruments that can read at least 100 mSv/h are not available, then extra care should be taken to ensure the instrument is not saturated.

Beta and X-ray contamination measurements may not be possible in the presence of significantly elevated gamma fields.

Visual identification of a source may be very difficult. Make sure you turn the instrument on well before attending the incident location.

It is expected that the presence of neutron radiation would be a very rare situation for a RED incident, as such sources are difficult to obtain. Neutron radiation would be associated with primitive nuclear devices.

- Surface wipe sampling from approximately 100 cm^2 from a horizontal smooth surface [Information E.18:2e]
- Neutron dose rate measurements; and

(f) If gamma dose rates do not increase by a factor of 10, take measurements and samples as detailed in (e) above every 50 metres. (Note that as walking in a straight line may be difficult, this can be interpreted as every 50 paces).

3. (ENVIRONMENTAL MONITORING TEAM, TIC)
If elevated gamma dose rates (and/or neutron dose rate) are found, advice is needed from TIC on occupancy times.

4. If a "maximum permissible limit" [Section E.1.1] on gamma dose rate (and/or neutron dose rate) is reached (or reading exceeds instrument full-scale):

(a) Determine location (e.g. building, street name, distance from three fixed points or GPS reading);
(b) Mark location with spray paint (if available) or other visible means;
(c) Retreat quickly to a "safe" position (return by the entry path); and
(d) Report information described below [Instruction E.22].

5. If gamma dose rate remains below 2x background, carry out the following measurements:

(a) Alpha contamination measurements on "hard" upward-facing surfaces;
(b) Beta contamination measurements on "hard" upward-facing surfaces;
(c) X-ray/low energy gamma contamination measurements;
(d) Neutron dose rate measurements; and
(e) Surface wipe samples should also be taken for later analysis.

6. If position of source is identified [Information E.21:2b], or because measured quantities reach maximum values, determine location, mark location, take the following measurements and samples:

Information E.21:2c

Indicators of a possible RDD

- Gamma dose rates > 100 μSv/h at 1 m above the ground;
- Alpha contamination measurements above background;
- Beta contamination measurements above background; and/or
- X-ray/low energy gamma contamination measurements above background.

Indications of a RED or other dangerous source

- Gamma dose rates > 100 μSv/h at 1 m from an object;
- Presence of neutron radiation;
- Medical symptoms of radiation injuries such as vomiting, diarrhoea and unexplained erythema [Section F.2.2.2];
- A heavy container with the radiation symbol [Figure E3];
- Item with radioactive transport labels [Figure E3];
- Item with transport UN numbers or markings indicating a radioactive material [Table E5];
- Device used for cancer treatment (teletherapy or brachytherapy);
- Radiography cameras or source (e.g. Figure E4 and E5); or
- Well logging sources used in drilling operations.

(a) Peak gamma dose rate;
(b) Peak alpha contamination count rate;
(c) Peak beta contamination count rate;
(d) X-ray/low energy gamma contamination measurements; and
(e) Neutron dose rate.

Note that if activity has been dispersed there may be several areas of very high contamination.

7. If elevated gamma dose rate is present and no alpha or beta contamination is found, then a surface wipe sample should be monitored with a gamma contamination monitor. This will determine if radionuclides which only produce gamma rays are present in the environment [Annex 11].

E.22 **Reporting results**

(ENVIRONMENTAL MONITORING TEAM)

1. Retreat to a "safe" position along the route of entry, report information described below.
2. Report the following information to TCP. A form which can be used is given in Annex 3:
   (a) Peak gamma dose rate, instrument used and location;
   (b) Peak alpha contamination count rate, instrument used and location;
   (c) Peak beta contamination count rate, instrument used and location;
   (d) Peak gamma/X-ray contamination measurement (if applicable), instrument used and location;
   (e) Peak neutron dose rate, instrument used and location; and
   (f) Locations of any surface wipe samples taken.

2.2 Contaminated food/water incidents

E.23 **Measurements**

(TIC)

1. Arrange for monitoring to confirm that the identified food/water source is contaminated.

Information E.23

Methods of analysis for alpha and beta emitting radionuclicles can be found in IAEA TECDOC 1092, 1999.

2. As monitoring is likely to be carried out in a laboratory after collection of samples, identify laboratories with appropriate expertise and arrange for samples to be collected and transported to the laboratory [Annex 11].
3. Rapid gamma-spectrometry measurements will be required on samples of food/water.
4. If a radionuclide is identified, that is an alpha emitter, rapid alpha spectrometry measurements (or possibly mass spectrometry for very long-lived radionuclides) are required to determine activity concentrations. Note that radiochemistry will be required, which will limit the rate of analysis.
5. If a radionuclide is identified, that is a beta emitter without significant gamma-ray emissions (e.g. Sr-90), rapid beta measurements are required to determine activity concentrations. Note that radiochemistry will be required, which will limit the rate of analysis.
6. An extensive monitoring programme is required to determine activity concentrations and the extent of contamination of food/water.

E.24 Identification of a radiological incident

(PUBLIC HEALTH AUTHORITY)

1. An incident may be discovered by routine monitoring of soil, air, water or food supply, but this is probably unlikely.
2. Information on possible contamination may be provided by means other than monitoring, for example, as a result of police intelligence or credible information from a terrorist organisation.
3. Contamination may be discovered by epidemiological surveillance of the population or public health reports leading to a suspicious pattern of illness [Section K.7].
4. If intelligence reports suggest radioactive contamination, then a programme of measurements should be considered. The nature of this programme will depend on the intelligence reports.
5. If the radionuclide concerned is unknown, then efforts should, at first, be concentrated on radionuclides which are listed in Table H1 [Information H.13 and H14].

3 Establishing zones and zone boundaries

Introduction

Zones are established around the scene of an incident to:

- Identify the affected population;
- Protect and control the public;
- Protect and control members of the emergency services;
- Facilitate the operations of all agencies;
- Guard the scene; and
- Prevent unauthorised interference with evidence or property.

The Red Zone is the potentially hazardous area immediately surrounding the incident where extreme caution and safety measures are required. Responsibility for the health and safety of personnel working within the Red Zone remains with the individual agencies involved. The cordon surrounding this zone is called the "Safety Perimeter".

The Yellow Zone surrounds the Red Zone and provides a safe and secure working environment for personnel and members of the public being processed for clearance from the incident. The cordon surrounding this zone is called the "Security Perimeter".

The security forces, in consultation with other agencies, will establish the size and position of each zone. The sizes of each zone will invariably be a compromise between the emergency services (wanting as much space as possible to function effectively) and the security services (wanting to limit the area to minimise resources required to maintain its integrity).

The two algorithms [Figures E7, E8 and E10] can be used to assist in the positioning and possible repositioning of the Safety and Security Perimeters.

3.1 Initiate the Red Zone

See Figure E6, "Generic layout of Red Zone".

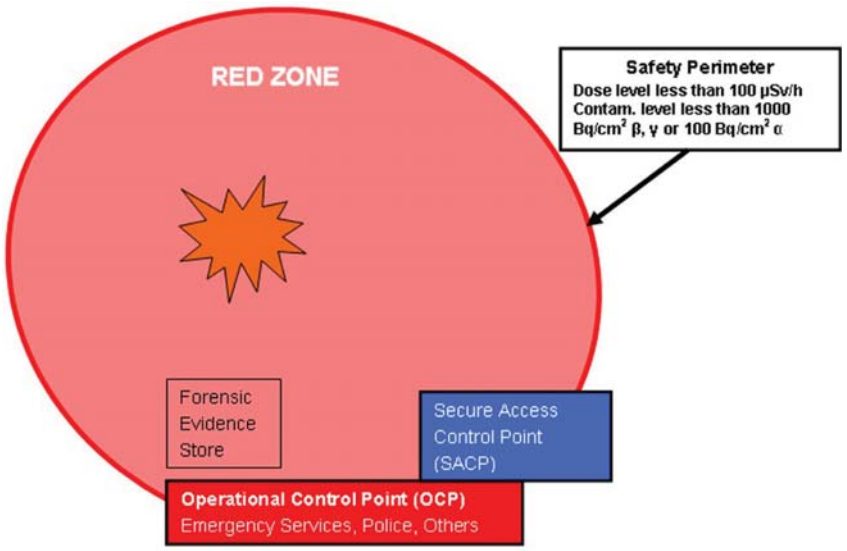


Figure E6. Generic layout of Red Zone.

E.25 **Establishing the Safety Perimeter**

(TIC, SECURITY PERSONNEL)

Unless it is safe to locate the Safety Perimeter nearer the incident, surround and secure the immediate area by establishing a Safety Perimeter at least 400 m radius from the incident. Where possible, use existing natural boundaries such as roads, rivers, buildings etc.

E.26 **Control of access**

(SECURITY PERSONNEL)

Install physical barriers with well defined "gateways" and security personnel at public thoroughfares, to control the movement of people by evacuating members of the public and excluding non-essential personnel from the Red Zone.

E.27 **Restriction of access**

(FIRST RESPONDERS, SECURITY PERSONNEL)

Access to the Red Zone must be restricted to emergency workers who should be:

- Logged in and out of this area;
- Using appropriate PPE [Information E.1]; and
- Minimising their exposure [Section E.1].

E.28 **Limits on dose rates and contamination levels at the Safety Perimeter**

(FIRST RESPONDERS)

Dose rates at the Safety Perimeter must not exceed 100 μSv/h and contamination levels must not exceed 1000 Bq/cm^2 for β/γ emitters, and 100 Bq/cm^2 for α emitters [Table F2]. However, there could be debris ("hot spots") present from the original incident/explosion. These should be identified by marking in some way (e.g. spray paint/cones/tape etc.) and/or removed as soon as possible to a Waste Store [Instruction E.48] or the Safety Perimeter extended to include them [Instruction E.29].

E.29 **Regular review**

(FIRST RESPONDERS, SECURITY PERSONNEL)

Regularly review the position of the Safety Perimeter and, if approved by the Tactical Incident Command, reposition the Safety Perimeter using Figures E7 and E8, Red Zone algorithm.

Information E.25

For safety reasons, such as the possibility of high dose rates, the threat of an explosion, or the instability of the area, the Safety Perimeter should initially be established no closer than 400 metres radius from the incident.

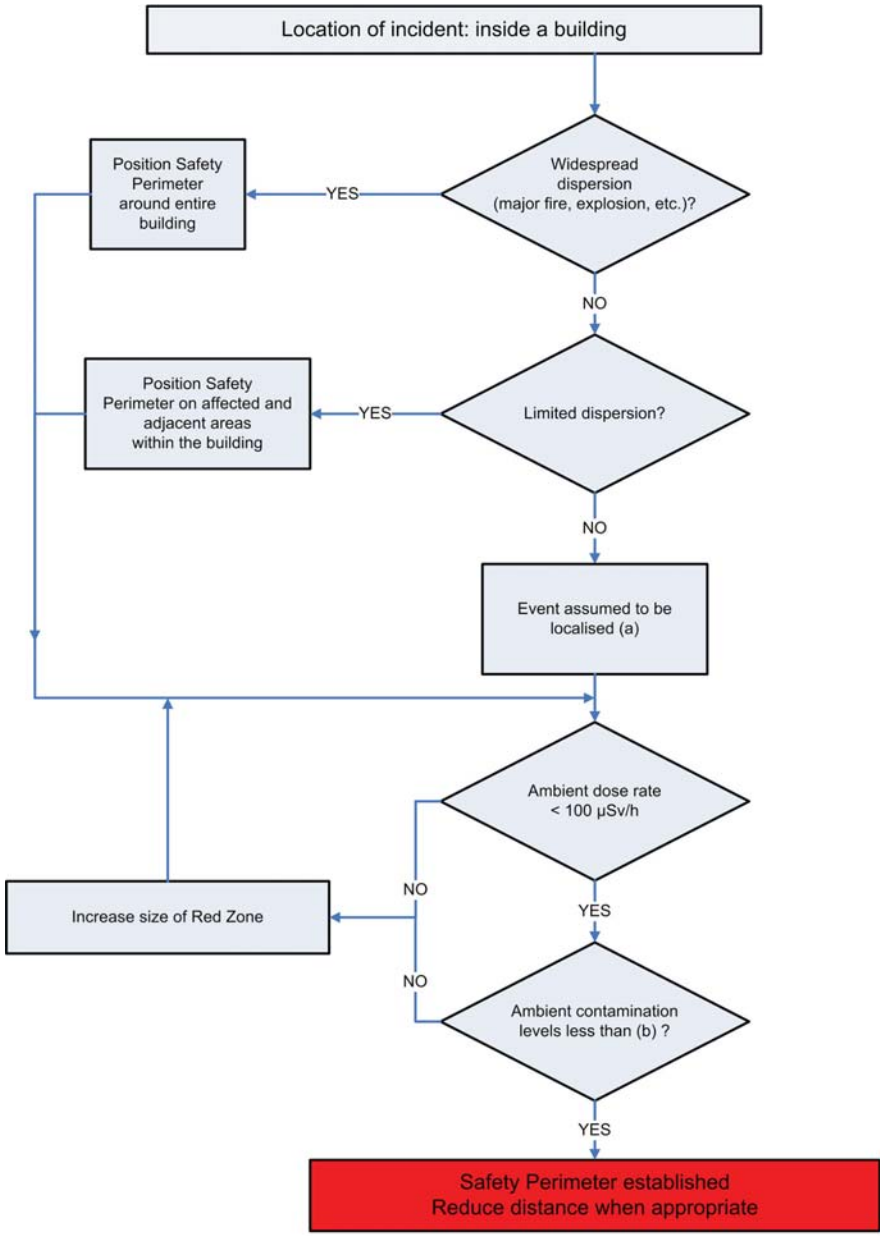
Set at a radius of 400 metres, the Safety Perimeter will extend for more than 2500 metres and enclose an area greater than 500,000 square metres, which in a city, could contain a large number of people. Considerable resources will be required to maintain the integrity of the Safety Perimeter and to deal with the "potentially" exposed people. Ideally the area of the Red Zone should be reduced as soon as practicable BUT only after receiving confirmation from Tactical Incident Command that it is safe to do so.

Alternatively, conditions may dictate that the distance between the safety perimeter and the incident be increased i.e. the spread of radioactive contamination and/or dose levels, risk of explosion, direction of plume, unstable structures.

The Red Zone can be an irregular shape and its size and shape will likely change as more information becomes available.

Information E.28

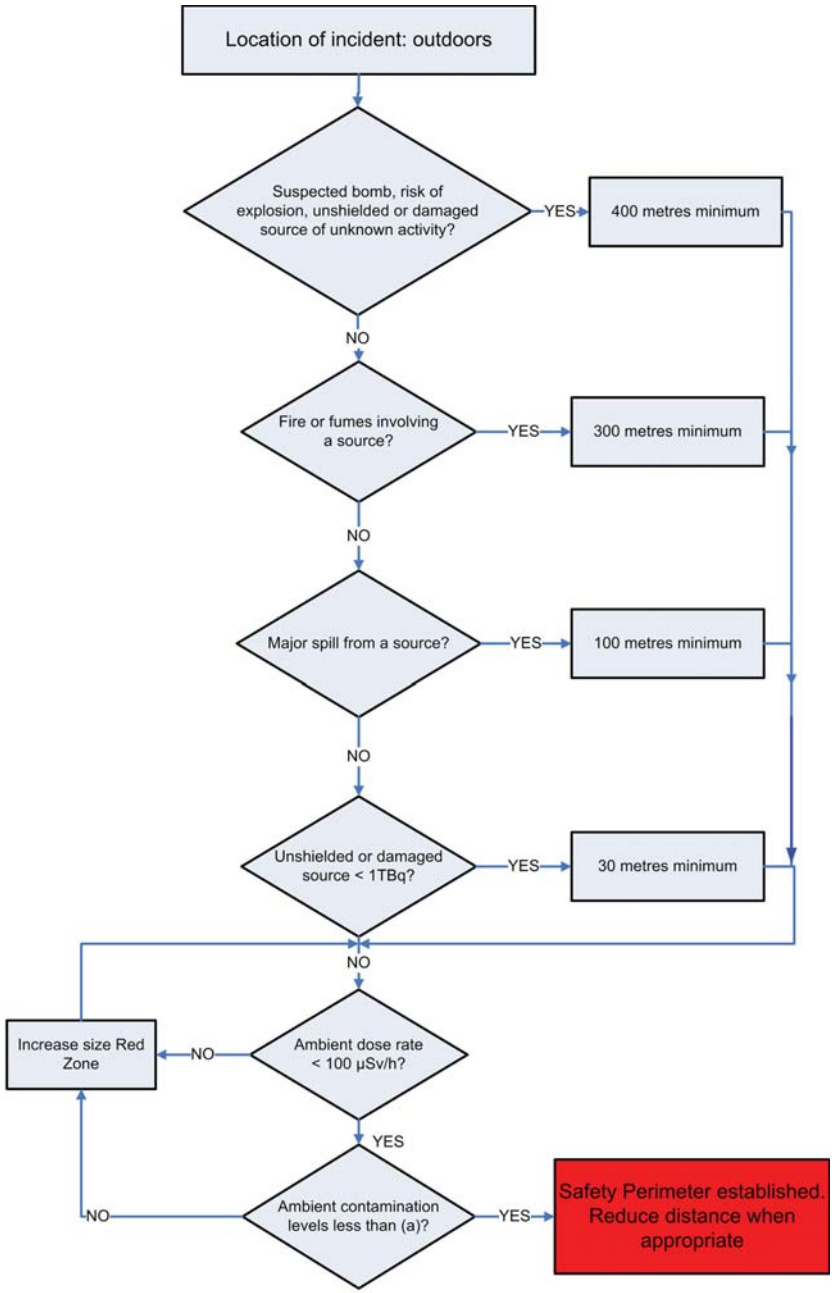
All radioactive waste should be properly handled at an early stage and at each level (scene of the event, evacuation, hospital departments etc). All waste must be treated as potential evidence, but waste should be evaluated for its significance as evidence, as waste preservation may pose a greater radiological problem than its disposal. Waste materials that do not require preservation should be disposed of properly, seeking guidance from the appropriate regulatory authority if required.



(a) Examples: damage to a source, spillage of material, loss of shielding

(b) 1000 Bq/cm^2 beta, gamma or 100 Bq/cm^2 alpha

Figure E7. Red Zone Algorithm (Part A)



(a) 1000 Bq/cm^2 beta, gamma or 100 Bq/cm^2 alpha

Figure E8. Red Zone Algorithm (Part B)

3.2 Initiate the Yellow Zone

See Figure E9, "Generic layout of Yellow Zone".

E.30 Establishing the TCP

(TIC)

The Tactical Command Point (TCP) should be sited outside the Red Zone, in a location that provides shelter and is safe, secure, convenient for directing operations, and to where emergency services are able to deploy their command and control vehicles.

E.31 Establishing the Security Perimeter

(TIC, SECURITY PERSONNEL)

The Tactical Incident Command, in consultation with the emergency and security services, should use Figure E10 "Yellow Zone algorithm" to establish the size and position of the Security Perimeter.

E.32 Control and restriction of access

(SECURITY PERSONNEL)

Use natural boundaries (roads, rivers, buildings etc), where possible, and install physical barriers with well defined ‘gateways’, manned by security staff, at public thoroughfares to control the movement of people through the Security Perimeter. Access to the Yellow Zone must be restricted to authorised staff.

E.33 Monitoring

(ENVIRONMENTAL MONITORING TEAM)

Initiate routine monitoring (surface contamination and large volume air sampling) to confirm the Yellow Zone is not becoming contaminated and that the Red Zone is not expanding.

E.34 Limits on dose rate and contamination levels at the Security Perimeter

(ENVIRONMENTAL MONITORING TEAM)

Dose rates in this area should be below 100 µSv/h, and contamination levels below 1000 Bq/cm^2 for β/γ emitters and 100 Bq/cm^2 for α emitters [Table F2]. However there could be debris ("hot spots") present from the original incident/explosion. These

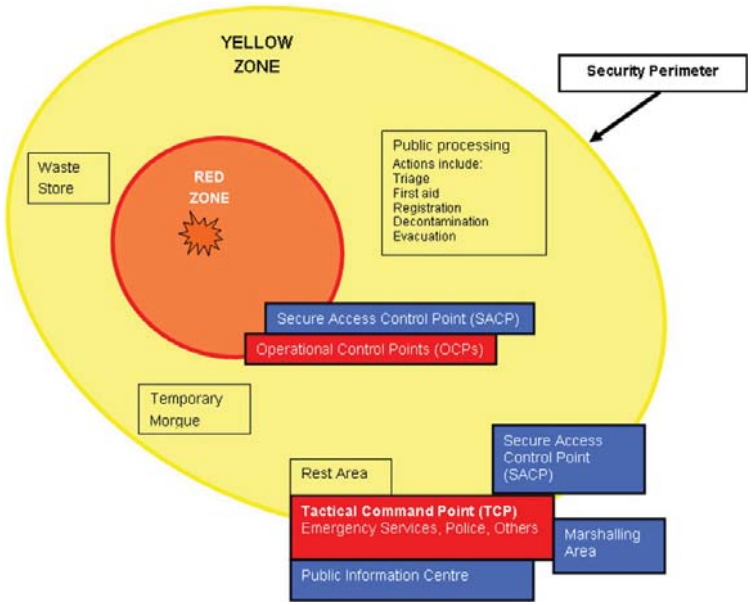


Figure E9. Generic layout of Yellow Zone.

Information E.30

Tactical Command Point (TCP) is the point from which on-scene management and co-ordination of the incident takes place. It is also the point of contact for other agencies with a part to play at the scene.

Information E.31

The extent of the Yellow Zone will inevitably be a compromise between the emergency services, requesting a large area to function efficiently, and security services, reducing the area according to resources available to maintain its integrity.

The larger this area becomes then the more people are needed to control it for decontamination, monitoring, evacuating etc.

The priority is to establish a Security Perimeter to identify the outer boundary of the Yellow Zone. The Yellow Zone can be an irregular shape and its size and shape may change depending on the activities being performed in this area.

should be identified by marking in some way (eg. spray paint/cones/ tape etc) and/or removed as soon as possible to the Waste Store [Instruction E.48].

E.35 **Regular review**

(TIC, SECURITY PERSONNEL)

Regularly review the area requirements of the Yellow Zone and the position of the Security Perimeter and, if approved by the Tactical Incident Command, reposition the Security Perimeter using Figure E10, "Yellow Zone algorithm".

3.3 Evolution of the Red Zone

See Figure E6, "Generic layout of Red Zone".

E.36 **Establishing the Secure Access Control Point (SACP)**

(TIC, SECURITY PERSONNEL)

As soon as practicable a single 'gateway' on the Safety Perimeter should be developed into a Secure Access Control Point (SACP) to provide controlled rapid access between the Red and Yellow Zones without compromising the safety of those involved.

E.37 **Purpose of the SACP**

(SECURITY PERSONNEL)

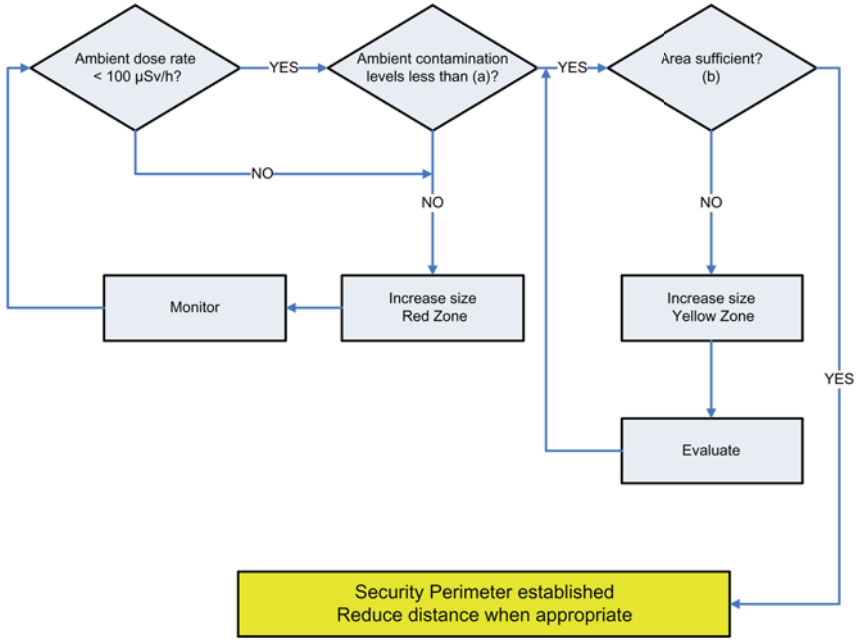
All emergency, specialist and voluntary services personnel should enter and exit the Red Zone through the SACP to ensure that they:

- Can be accounted for (logged in and out of the Red Zone);
- Are briefed on their duties and any associated hazards;
- Are deployed when appropriate;
- Are using the appropriate PPE [Information E.1] and that it is functioning before entering the Red Zone; and
- Wearing some form of identification (e.g. high visibility uniform, armbands, jacket, headgear).

E.38 **Establishing Operational Control Points (OCPs)**

(TIC, SECURITY PERSONNEL)

Establish Operational Control Points (OCPs) inside the Red Zone, on the Safety Perimeter, away from the public processing area [Section E.1].



(a) 1000 Bq/cm² beta, gamma or 100 Bq/cm² alpha
(b) For requirements of emergency services AND access through Security Perimeter can be controlled effectively

Figure E10. Yellow Zone algorithm.

Information E.36

The correct location of the SACP on the Safety Perimeter is of the utmost importance as this site will probably be developed into the Operational Control Point (OCP).

Information E.38

The functions of Operational Control Points (OCPs) include securing rapid gateways for emergency personnel/equipment/transport and the rapid 'screening' of minor casualties and first responder personnel (and equipment).

Agencies may be located together or separately.

E.39 **Establishing transit routes**
(FIRST RESPONDERS)
Develop well defined and identified "safe" transit routes from the SACP toward the incident, for use by emergency personnel [Section E.1].

E.40 **"Hot spots"**
(FIRST RESPONDERS)
Areas of high contamination or dose rates ("hot" spots) must be identified and labelled (using spray paint/tape/cones etc) or, if possible, removed to a radioactive waste storage area.

E.41 **Monitoring transit routes**
(ENVIRONMENTAL MONITORING TEAM)
Transit routes should be routinely monitored to confirm they are remaining "safe" and not becoming further contaminated.

E.42 **Forensic evidence**
(SECURITY PERSONNEL)
A Forensic Evidence Store should be designated within the Red Zone for the safe and secure storage of evidence recovered from the scene and for maintenance of the continuity and integrity of evidence.

3.4 Evolution of the Yellow Zone

See Figure E9, "Generic layout of Yellow Zone".

E.43 **Establishing the Secure Access Control Point (SACP)**
(SECURITY PERSONNEL)
As soon as practicable, a single gateway on the Security Perimeter should be developed into a Secure Access Control Point (SACP).

E.44 **Purpose of the SACP**
(SECURITY PERSONNEL)
All emergency, specialist and voluntary services should be directed to the SACP for logging, briefing, equipment issue and deployment.

Information E.43

The correct location of the SACP on the Perimeter is important because the SACP is used to rigorously control the movement of emergency personnel through the Security Perimeter, without compromising the safety of those involved, and prevent unauthorised personnel and members of the public entering the Yellow Zone.

Information E.45

The Public Processing Area will comprise a Reception Centre and Radiation Monitoring Unit.

Reception Centre
The Centre should be set up at a location where people not requiring urgent medical treatment following an emergency can be sent for:

- Shelter;
- Triage;
- Rest;
- Medical treatment;
- Collection of information from affected individuals;
- Provision of information to affected individuals; and
- Counselling of affected individuals.

It is expected that people evacuated from within the Security Perimeter should be directed to the Public Processing Area. People returning after having left the scene would be directed to similar facilities set up outside the Security Perimeter.

Radiation Monitoring Unit
Associated with the Reception Centre a Radiation Monitoring Unit may be established. This may be located in the same building as the Reception Centre or located in a separate nearby building. People should be monitored at the Radiation Monitoring Unit and, if necessary, decontaminated, before entering the Reception Centre.

The Radiation Monitoring Unit should have:

- A segregated area for people waiting for decontamination;
- An area for external contamination measurements;
- An area for decontamination of people;
- An area for internal contamination monitoring (if available);
- Storage for replacement clothing;
- Storage for contaminated clothing and other contaminated items;
- An area for recording and reporting information with communications equipment; and
- An area for counselling concerned individuals.

E.45 **The Public Processing Area**

(TIC, ALL TEAMS)

Ideally, this area should be covered with good access to both SACPs, and be large enough to achieve the following tasks:

- Processing and registering the public evacuated from the Red Zone [Section H.6, Annex 3];
- Radiological triage, medical treatment and preparation of patients for transport [Chapter F]; and
- Monitoring and decontamination of the public evacuated from the Red Zone [Section F.3, Chapter G].

E.46 **Monitoring the Public Processing Area**

(ENVIROMENTAL MONITORING TEAM)

Routinely monitor the Public Processing Area to ensure that ambient dose and contamination levels remain low (close to natural background values) and the area is not becoming unsafe. If the ambient dose rate exceeds 100 μSv/h and/or contamination levels exceed 1000 Bq/cm^2 for β/γ emitters or 100 Bq/cm^2 for α emitters, then the Public Processing Area should be moved to another location with lower levels of dose and/or contamination.

E.47 **Rest area for emergency response personnel**

(TIC)

Establish a safe, secure and sheltered area, away from the view of the public, where off-shift personnel can rest and receive refreshment.

E.48 **Storage of radioactive waste**

(ENVIROMENTAL MONITORING TEAM, SECURITY PERSONNEL)

If required, designate a Waste Storage Area away from the Public Processing Area and preferably in a building to prevent the spread of contamination, to where radioactively contaminated debris can be removed and potentially contaminated items (e.g. clothing) can be stored. Contamination and dose levels in this area should be monitored regularly to ensure that the accumulation of contaminated waste does not pose a health threat to those using the facility.

Information Section E.3

Additional Information on Establishing Zones and Boundaries

The description of zones and zone boundaries presented in this Handbook is based on the guidance in IAEA (IAEA TECDOC 1162, 2000). Many other schemes exist for setting zones and zone boundaries and it is not possible to present them all. However, these all share many of the characteristics of the IAEA scheme.

The "safety perimeter" may be known as the "exclusion perimeter" or "inner cordon", and similarly the "security perimeter" may be known as the "outer cordon". Other perimeters may be created for logistical purposes, for example a cordon may be created outside of the security perimeter to prevent access to unauthorised vehicles. Several other systems include an area of the "Red Zone" where dose rate exceeds 100 mSv/h and where access is allowed only for life saving actions and residence time is restricted to avoid large doses to first responders. (Continued over page)

E.49 **Temporary Morgue**

(FIRST RESPONDERS, MEDICAL TEAM, SECURITY PERSONNEL)

If required designate a Temporary Morgue, sheltered and away from the Public Processing Area. Facilities should be provided for grieving family members and associates.

3.5 Outside the Yellow Zone

See Figure E9, "Generic layout of Yellow Zone".

E.50 **Establishing a Marshalling Area**

(TIC, ALL TEAMS)

Identify a secure area to act as a Marshalling Area in close proximity to, or with communication with, the TCP, where resources and personnel arriving at the scene, being held for further use or not immediately required at the scene, can be directed to standby.

E.51 **Establishing the Public Information Centre**

(TIC, ALL TEAMS)

Identify a secure area to act as a Public Information Centre in close proximity or communication with the TCP with space and the infrastructure to support media briefings.

E.52 **Establishing a Public Processing Area outside of the Yellow Zone**

(TIC, ALL TEAMS)

A Public Processing Area should be established for people who were evacuated from the Yellow Zone without being monitored or decontaminated [Information E.45].

Information Section E.3 (cont.)

It is probable that some time after the incident, additional zones may be created when extensive environmental monitoring data is available; one scheme is presented below which is based on access restriction.

Zone Designation	Admission Rules
Red Zone	Permission needed to enter
Orange Zone	Access only to those who live and work in this zone
Yellow Zone	People are advised not to enter

Similar schemes subdivide the 'red zone' on the basis of dose rates, which determine the actions that can be taken. An example is illustrated below from the U.S. Conference of Radiation Control Program Directors (www.crcpd.org).

Table E6. An example of subdivision of the Red Zone.

Zone Designation	Zone Dose rates, mSv/hr	Action Allowed in the zone
Extreme Caution Radiation Zone	≥ 100	▪ Activities restricted to saving lives ▪ Total accumulated stay time for first 12 hours: minutes to hours
High Radiation Zone	10	Access restricted to authorized personnel performing critical tasks: ▪ Fire fighting ▪ Medical assistance ▪ Rescue ▪ Extrication ▪ Other time-sensitive activities
Medium Radiation Zone	1	▪ Access restricted to authorized personnel entering the "High Radiation Zone" to perform critical tasks such as saving of lives and property ▪ Serves as a buffer zone/transition area between the "High Radiation Zone" and "Low Radiation Zones"
Low Radiation Zone	0.1	▪ Access restricted to essential individuals ▪ Initial decontamination of first responders should occur near the outer boundary of this area

CHAPTER F

Triage and monitoring for the purpose of screening

1 Objectives of triage

Triage is the use of simple procedures for rapidly sorting people into groups based on (a) their degree of physical injury and (b) actual or potential effects on health, and the allocation of care [Information Section F.1b] to these people in order to expedite treatment and maximise the effective use of resources.

Triage is a fundamental part of the response to accidents (such as road traffic accidents) or natural disasters (floods, earthquakes, etc.). In such events, triage is designed to allocate medical treatment and resources according to the urgency of the patients' need for care. This process is intended to maximise the number of survivors and can be termed "trauma triage".

Trauma triage may be required following incidents involving the malevolent use of radiation or radioactive material in a public place. However, the scope of triage is broader for such incidents and includes a group of actions that can be termed "radiological triage". These actions are intended to sort people rapidly into groups depending on actual or potential effects on their health resulting from radiation exposure.

A widely-used trauma triage system allocates people into one of three categories:

- Category P1 (Priority 1) is used for severely injured people who require immediate life-saving intervention;
- Category P2 (Priority 2) is used for people with less severe injuries who will need hospital care, but whose transfer to a medical facility may be delayed for 10 – 12 hours; and

Information Section F.1a

Suspected presence of chemical or biological agents
If chemical or biological contamination is suspected, then procedures for this type of incident **MUST** take precedence over those described in this Handbook.

Information Section F.1b

Types of "care"
The care allocated to the various groups of people identified by the triage process, ranges from "high intervention" measures such as urgent treatment of injuries (trauma triage categories P1 and P2) or treatment of life-threatening radiation exposures (radiological triage categories II or III), to "low intervention" measures, such as long-term radiological protection follow up through a programme of monitoring measurements designed to provide information on potential long-term effects on health.

Trauma triage categories are defined opposite.

Radiological triage categories are defined in Section F.2.2.2.

- Category P3 (Priority 3) is used for injured people who will require medical care but may wait for a number of hours or be told to go home and return the next day (the "walking wounded").

It is important to be clear about the objectives of the triage process. These objectives are presented below in order of urgency. Objectives 1, 2 and 3 constitute the aims of trauma triage; they are to identify:

1. People who should be assigned to Category P1 (Priority 1).
2. People who should be assigned to Category P2 (Priority 2).
3. People who should be assigned to Category P3 (Priority 3).

Objectives 4, 5 and 6 constitute the aims of radiological triage; they are to identify:

4. Those people who have been exposed (or are still being exposed) to radiation or radioactive material at a level that will definitely have an effect on their health (e.g. as a result of acute radiation syndrome).
5. Those people who may have been exposed (or are still being exposed) to radiation or radioactive material at lower levels that might nevertheless have an effect on health. In general these would be longer term effects such as cancer.
6. The potentially large groups of people whose exposures are very unlikely to have an effect on health, or who were not exposed at all. Once identified, these groups may be excluded from further consideration for medical treatment or monitoring.

Section F.2 describes the process of field triage in the event of an incident involving the malevolent use of radiation or radioactive material. The term "field triage" is used to describe all those triage procedures that are carried out on the affected population outside of a hospital or other medical facility, either at the site of the incident or at a distance from it. Its scope includes all of the triage decisions made from the commencement of the incident up until the time when all people are correctly categorised for triage purposes (assumed to be about 6 days following the incident), or up to the admission of a particular individual to a medical facility. The various stages in the field triage process are described in Information Section F.1c.

Information Section F.1c

Stages in the triage process

Triage following an incident involving the malevolent use of radiation or radioactive material is a multi-stage process that would be carried out over an extended period of time. A major problem will be to differentiate those needing care from the potentially large numbers of people who require only information and reassurance (often known as the "worried well"). In the early stages, triage decisions will have to be based on limited information, and will concentrate on the identification of those with an urgent need for treatment. In the later stages, more information (such as the results of initial monitoring) will be available, and triage will be extended to the identification of groups requiring "low intervention" care [Information Section F.1b].

Table F1. Stages in the triage process.

Triage Stage		**Typical time period when triage decisions will be made**	**Information available**
Trauma	Pre-monitoring	0-12 h	Severity of physical injuries to individuals
Radiological	Pre-monitoring	2-36 h	Location, etc., at time of incident
	Pre-monitoring	0 h – 6 days	Clinical signs and symptoms, and in the later stages, the results of complete blood counts
	Post monitoring	6-72 h	Results of initial screening measurements made at incident location
	Post monitoring	12 h – 6 d	Results of measurements made with transportable *in vivo* monitoring facilities close to incident location
	Post monitoring	24 h – 6 d	Results of laboratory *in vivo* monitoring measurements
	Post monitoring	72 h – 6 d	Results of laboratory *in vitro* measurements of biological samples (e.g. radionuclides in urine, cytogenetic measurements of blood, etc.)

Notes.
1. The results of radiological monitoring will continue to be received well beyond the end of the period where triage decisions are expected to be made. For some cases, the same will apply to the results of observations of clinical signs and symptoms.
2. For some types of incident, not all of these triage stages would arise.

2 Initial triage

Introduction

Initial stages of triage

The required actions are described in the order of urgency in which the various stages of triage need to be carried out. However, preparations for each stage of triage need to be initiated in a timely manner. Preparations for the next stage of triage cannot await the completion of the previous stage. The teams required to carry out the various roles are described in Annex 4.

The initial stages of triage are likely to take place before the results of radiological monitoring of individuals are available. It is assumed that first responders (i.e. paramedics or ambulance staff) will have commenced trauma triage by the time the actions described in this section are carried out. These actions are summarised in Figure F1.

2.1 Trauma triage

F.1 **Identifying people with trauma injuries**
(TACTICAL INCIDENT COMMAND [TIC], FIRST RESPONDERS, MEDICAL TEAM)
If traumatic injuries have occured, contact should be established with first responders dealing with people with such injuries. The Incident Commander at the Tactical Control Point should facilitate this contact [Section E.3]. Information on identity, location at time of incident, and triage category should be recorded for patients who have been processed through the trauma triage system [Annex 3]. This must not delay or interfere with treatment of trauma injuries. It should be possible to carry out this task in the Public Processing Area of the Yellow Zone [Section E.3].

If there are no trauma injuries, proceed to Section F.2.2.

Information F.1a

Trauma triage
The first responders dealing with trauma injuries are likely to be the first on the scene.

People with trauma injuries are the first group of people who should be identified. If trauma injuries have resulted from an explosion, people in this group should be assumed to be contaminated, both externally and internally, by radioactive material.

Treatment of life-threatening trauma injuries must always take priority over all actions relating to radiation protection, UNLESS radiation exposure is life-threatening to either patient or first responder. An example would be where the patient is exposed to very high dose rates because of proximity to a radiation source. Here, the highest priority would be to reduce the dose rate by removing the patient from the immediate environment of the source [Section E.1].

Trauma injuries may well be absent if the incident did not involve an explosion or aggravated method of attack.

Information F.1b

The trauma triage system described in the Handbook employs three categories, P1, P2, P3 [Section F.1]. There may be differences between this system and some national triage systems, but these differences are not significant.

F.2 **Assessing people with trauma injuries**
(ENVIRONMENTAL CONTAMINATION INCIDENTS) (MEDICAL TEAM)
It should be assumed that patients in trauma triage categories P1, P2 and P3 are both externally and internally contaminated with radioactive material. In the absence of reliable information on location, assume that these patients were within the Red Zone at the time of the incident.

F.3 **Transfer of Category P1 patients to hospital**
(MEDICAL TEAM)
Patients in category P1 must be transferred to hospital immediately, without carrying out decontamination procedures (unless chemical or biological contamination is suspected). First responders should communicate the fact that no decontamination has been carried out to those responsible for transferring the patient to hospital, for onward transmission to hospital staff receiving the patient [Chapter I].

F.4 **Decontamination of Category P2 patients**
(MEDICAL, DECONTAMINATION TEAMS)
Patients in category P2 are likely to have serious injuries, but hospital care may be delayed (perhaps for 10 – 12 hours, but determined on a case-by-case basis). Patients in category P2 should be decontaminated at the site of the incident before transfer to hospital, if possible [Chapter G]. If this is not possible, facilities for handling contaminated casualties must be established at the receiving hospital [Section J.2, Section J.6].

F.5 **Decontamination of Category P3 patients**
(MEDICAL, DECONTAMINATION TEAMS)
Patients in category P3 ("walking wounded") should be decontaminated at the location of the incident, or provided with instructions on decontamination to be followed when they return home [Chapter G]. They must not be directed to a hospital for decontamination. Medical treatment will have a lower priority than that for P1 and P2 groups. It may be delayed for 24 hours or more, and could be carried out in an Outpatients Department of a hospital or other medical facility, where a second triage will be performed [Section J.4].

Information F.2

It is probable, though not certain, that patients in groups P1, P2 and P3 will be among the most heavily contaminated, both externally and internally. Furthermore, P1 may be more heavily contaminated than P2, and P2 more than P3.

Information F.3

Suspected presence of chemical of biological agents
If chemical or biological contamination is suspected, then procedures for this type of incident MUST take precedence over those described in this Handbook.

Information F.4

Presentation of a large number of contaminated patients to a hospital may result in saturation of its capabilities to provide medical treatment.

F.6 Initiation of radiological triage

(RADIOLOGICAL TRIAGE TEAM)

All patients assigned to trauma triage categories P2 and P3 should, as soon as practicable, be subjected to radiological triage based on clinical signs and symptoms [Section F.2.2.2].

These patients should then be subjected to radiological triage based on information on location at the time of the incident [Section F.2.2.1].

F.7 Monitoring of trauma triage patients

(RADIOLOGICAL TRIAGE, MEDICAL, PEOPLE MONITORING TEAMS)

All patients assigned to trauma triage categories P1, P2 and P3 should undergo initial monitoring (i.e. simple external and internal contamination measurements) as soon as their medical condition allows it. The aims of this monitoring are described in Section H.1. Section F.3 describes the decisions to be made regarding initial monitoring, and the criteria on which these decisions should be based. Decisions on when (or whether) monitoring can be initiated for patients assigned to trauma triage categories P1, P2 and P3, and the appropriate type of monitoring, must be made on a case-by-case basis, in consultation with medical staff who are responsible for the care of the individual.

F.8 Deceased people

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

Bodies of deceased people may constitute a radiological hazard. This issue should referred to the Tactical Incident Command [Annex 4 and Section J.9].

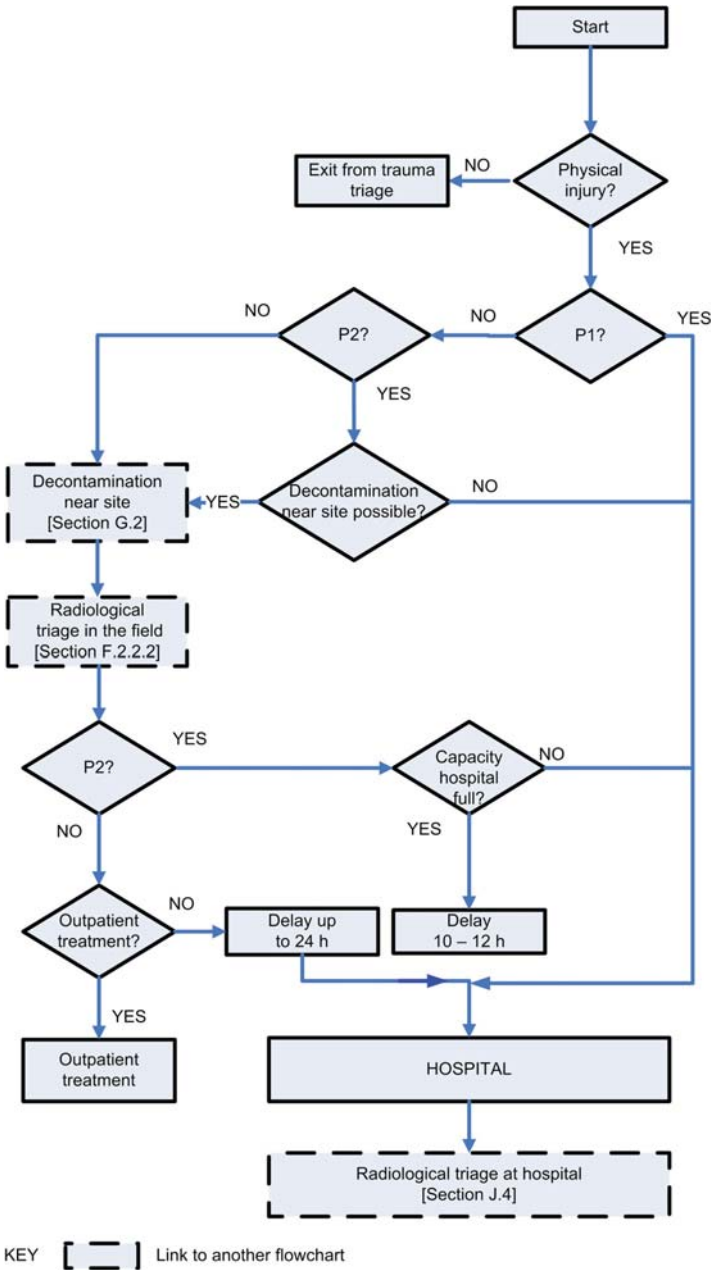


Figure F1. Flowchart for trauma triage.

2.2 Radiological triage

Introduction

The radiological triage procedures to be followed depend on the circumstances of the exposure (i.e. whether it was by direct irradiation, as a result of environmental contamination, or as a result of contamination of foodstuffs/water).

For most people, information on location will be the prime indicator of potential exposure in the initial stages of the response to an incident. For contamination incidents, individual monitoring will provide more reliable information, but the instruments and facilities to carry out such monitoring are unlikely to be available during the first few hours of the response.

Patients assigned to trauma triage categories P2 and P3 are not subjected to triage based on information on location because it is assumed that they are potentially the most highly contaminated, both internally and externally.

For all other groups of people (with the exception of those in category P1), radiological triage based on information on location is the first stage of triage [Figure F3].

2.2.1 *Triage based on information on location*

F.9 **Target groups for triage after irradiation incidents**
(EXTERNAL IRRADIATION INCIDENTS) (RADIOLOGICAL TRIAGE TEAM)
The following groups of people (with the exception of those in category P1, P2 and P3), must be identified and then subjected to radiological triage based on information on location relative to the source of irradiation:

- People who can be identified as being within a pre-defined distance from the location of the source of irradiation at any time during the specified time period [Section E.3.1]; and
- People who believe they may have been within a pre-defined distance from the location of the source of irradiation at any time during the period of time that people could have been irradiated [Section E.3.1].

Information F.9a

People selected according to bullet 1 may be identified by means of police intelligence, CCTV cameras, etc. These procedures are however beyond the scope of this Handbook.

Information F.9b

If information is available that provides strong evidence that the activity of the source is relatively small (i.e. less than 1 TBq), then this distance can be set at 30 m (but compliance with the dose constraint described in Instruction E.28 should be confimed urgently by monitoring [Section F.3.2]). If the source activity is larger, or there is no information on source activity, then the distance should be set at 400 m until monitoring is carried out that confirms that the distance can be reduced.

F.10 **Covert external irradiation incidents**
(EXTERNAL IRRADIATION INCIDENTS [COVERT])
(RADIOLOGICAL TRIAGE TEAM)
If the incident was covert (i.e. the location of the source was unannounced, or was unknown prior to detection), then it will not be possible to carry out Instruction F.9 fully until information is obtained on the location of the source during the period that it could have resulted in irradiation of members of the public. Such information must be obtained from intelligence sources. Procedures for obtaining such information are beyond the scope of this Handbook.

F.11 **Target groups for triage after environmental contamination incidents**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE TEAM)
The following groups of people must be identified and then subjected to triage based on information on location relative to the source:

- People who are emerging from the Red Zone set up around the source of contamination [Section E 3];
- People who believe they were within the Red Zone at any time since the incident, before or after the Safety Perimeter was set up. It will be necessary to define this area on a map so that streets and buildings can be identified; and
- In the absence of an established Safety Perimeter, people who were within 400 m of the source of contamination at any time since the incident. This includes people in the building or other enclosed location where the incident occurred at any time since the incident. The area should be delineated on a map so that streets and buildings can be identified.

The circumstances of the incident may dictate that other groups of people should be defined.

Information F.10

Covert scenarios
In the absence of adequate information on source location, greater reliance must be placed on triage based on clinical signs and symptoms [Section F.2.2.2] and on biological dosimetry [Section J.10] to identify affected individuals. Effective communications to the public using radio, TV and newspapers will be needed. It must be accepted that it will not be possible to identify everyone whose health may be affected by the incident.

Information F.11a

Effect of wind direction
Wind direction should not be used in the selection of people for this stage of triage. In an urban environment, wind direction is not a good indicator of potential exposure. Exposures seemingly upwind can be greater than downwind at the same distance from the source because of the complex airflow patterns around buildings.

Information F.11b

Zone boundaries
As the incident progresses, the position of the Safety Perimeter may change. If so, the area inside the Perimeter (i.e. the area of the *Red Zone*) is most likely to decrease, but be aware of the possibility that the *Red Zone* area could also increase. It is possible therefore that the numbers and identity of the people to be subjected to this stage of triage may change as the response progresses. Triage must be treated as a dynamic process, and the allocation of people to the various categories should be reviewed regularly.

F.12 **Covert environmental contamination incident**
(ENVIRONMENTAL CONTAMINATION INCIDENTS [COVERT]) (RADIOLOGICAL TRIAGE TEAM)
If the incident was covert (i.e. the location of the source of contamination was unannounced, or was unknown prior to detection), then it will not be possible to establish an adequate Safety Perimeter or to carry out Instruction F.11 fully until the results of comprehensive environmental contamination monitoring are obtained. This monitoring must be carried out with the highest priority [Section F.3.2]. Unless such monitoring can be guided by intelligence sources, it is likely to require a significant time, particularly if the contamination is by alpha-emitting radionuclides.

F.13 **Contacting affected people**
(EXTERNAL IRRADIATION & ENVIRONMENTAL CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE TEAM)
People identified according to Instructions F.9 or F.11 should be contacted using printed leaflets, announcements on radio and TV, by using an internet-based health information service or by telephone using call centres. People still within the Red or Yellow Zones should be invited to present themselves at a Reception Centre established within the Yellow Zone. Otherwise, they should be invited to present themselves at a Reception Centre established beyond the Yellow Zone.

F.14 **Decontamination**
(ENVIRONMENTAL CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE, DECONTAMINATION TEAMS)
People identified according to Instruction F.11 who have already returned home should be provided with advice on decontamination [Section G.3].

F.15 **Symptoms of ARS**
(EXTERNAL IRRADIATION & ENVIRONMENTAL CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE, MEDICAL TEAMS)
People identified according to Instructions F.9 or F.11 must be advised to contact immediately the appropriate authorities if they are suffering from nausea, vomiting or diarrhoea [Section K.7].

Information F.12

Covert environmental contamination scenarios
This instruction is likely to apply for scenarios involving the covert dispersion of radionuclides, i.e. not involving an explosion or obvious sabotage of a radioactive source. The site of any explosion may be assumed to be co-located with the source of contamination unless environmental or individual monitoring indicates otherwise.

In the absence of adequate information on source location, greater reliance must be placed on triage based on external and internal contamination monitoring [Section F.3 and Section H.4] to identify affected individuals. This is likely to involve a large-scale programme of radiological monitoring for members of the public. Effective communications to the public using radio, TV and newspapers will be needed. Triage based on clinical signs and symptoms [Section F.2.2.2] should also be employed as a supplementary method for identifying the most exposed individuals. It must be accepted that it may not be possible to identify everyone whose health may be affected by the incident.

Information F.13

Examples of a printed leaflet that could be handed out at the site of the incident, and a media release that could be provided to newspapers, radio and TV stations, are provided in Annex A3. A telephone- or internet-based health information service such as NHS Direct in the UK (http://www.nhsdirect.nhs.uk/) could also be used.

Information F.14

Many people will very quickly remove themselves from the scene of an incident, and they should not be prevented from doing so unless security personnel decide otherwise. It will not be possible to record personal information for such people at the scene of the incident. The approach should be to make announcements on radio and TV, as soon as possible, inviting people in “potentially at risk” groups to present themselves at an appropriate location such as a Reception Centre outside the Yellow Zone.

Information F.15

A caution
Many people who report these symptoms will not have been exposed to any significant extent to radiation or radioactive material, but may be experiencing symptoms because of stress and anxiety.

Nevertheless, it is extremely important that this message is given clearly, as it could save lives.

F.16 **Collection of information from potentially affected people, irradiation incidents**

(EXTERNAL IRRADIATION INCIDENTS) (RADIOLOGICAL TRIAGE, RECORDS TEAMS)

People identified according to Instruction F.9 should be contacted and more detailed information of the following types should be collected:

1. Name, date of birth, address, contact telephone number.
2. If direct physical contact took place:
   - Length of contact time;
   - Date, time of day this contact took place;
   - Did the individual move the source? and
   - If so, where from?
3. If no direct contact:
   - Length of time the subject was close to source;
   - Distance from the location where source was located; and
   - Within line of sight? If not, information on what lay between the source and the individual is needed (may be of use for shielding calculations).
4. If the incident took place in an enclosed space:
   - Whether on same or different floor of building; or
   - Whether on same or different platform in a station (similar criteria can be specified for other locations).
5. If the source was mobile, then the same criteria should be applied to every point on the track of the source during the period when irradiation of people could have taken place.

An example questionnaire that can be customised is provided in Annex 3.

F.17 **Collection of information from potentially affected people, environmental contamination incidents**

(ENVIRONMENTAL CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE, RECORDS TEAMS)

People identified according to Instruction F.11 should be contacted and more detailed information of the following types should be collected:

1. Name, date of birth, address, contact telephone number.

Information F.16 and F.17

Any people who are still in the *Red Zone* should be evacuated from the area before they are asked to provide this information.

Information F.16, F.17 and F.21

The radiation dose received by an individual close to a radioactive source increases in direct proportion to the amount of time spent close to it, but decreases rapidly with increasing distance (the inverse square law). The dose is reduced if other objects occupy the space between the source and the individual, particularly if the objects contain a lot of mass.

2. General:
   - Was there any direct contact with material released as a result of the incident (hit by debris, breathed fumes, etc.)? If so, and person has returned home, details of the journey (in case of transfer of contamination);
   - Whether inside or outside;
   - Activity at the time of the incident (running towards or away; driving towards or away; entering or leaving a building; etc.); and
   - The locations between which the person moved at the time of the incident.
3. If the incident took place in the open:
   - Distance from the source of contamination (0 – 400 m; > 400 m); and
   - Time of day, and length of time, at this location.
4. If the incident took place in an enclosed space:
   - Whether on same or different floor of building as the source of contamination;
   - Whether on same or different platform in a station, etc.; and
   - Time of day, and length of time, at this location.
5. If the source was mobile, then the same criteria should be applied to every point on the track of the source during the period when releases could have taken place.

An example questionnaire that can be customised is provided in Annex 3.

F.18 **Collection of information from potentially affected people**
(EXTERNAL IRRADIATION & ENVIRONMENTAL CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE TEAM)
Information collected on identity and location at time of incident must be recorded [Annex 3].

F.19 **Selection of people**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE TEAM)
On the basis of information collected according to Instruction F.17,

people who meet the following criteria should be selected for further consideration within the radiological triage process:

- All who came into direct contact with debris, fumes or other material originating directly from the primary source;
- If incident took place outside, then all those who were within 400 m of the source of contamination (or a smaller distance as defined in Section E.3) at any time since the incident;
- If incident took place inside, then everyone within the same enclosed space (e.g. a building) at any time since the incident. If in doubt, then everyone within 400 m of the source of contamination at any time since the incident; and
- If the source of contamination was mobile, then the same criteria should be applied to every point on the track of the source during the period when releases could have taken place.

F.20 **Prioritisation of people, environmental contamination incidents**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE TEAM)
The people selected according to Instruction F.19 should be prioritised using the information collected using Instruction F.17, as follows. Five categories are used: LOW, LOW – MODERATE, MODERATE, MODERATE – HIGH, HIGH. The following factors should be taken into account:

- If person came into contact with material released as a result of the incident, likelihood of exposure is HIGH;
- If incident was outside and individual was outside within 400 m of the source of contamination at the time of the incident, likelihood of exposure is MODERATE;
- If incident was outside and individual was more than 400 m away at the time of the incident, likelihood of exposure is LOW;
- If incident was outside and individual was inside at the time of the incident, likelihood of exposure is LOW;
- If incident was inside and individual was outside at the time of the incident, likelihood of exposure is LOW;
- If incident was inside, and individual was inside close to the site of the incident (e.g. on the same floor) at the time of the incident,

Information F.20

This categorisation scheme is completely separate from the trauma triage categorisation scheme (i.e. P1, P2 and P3) [Section F.1] and the radiological triage categorisation scheme (i.e. I, II and III) [Section F.2.2.2].

likelihood of exposure is MODERATE – HIGH;

- If incident was inside, and individual was inside at the same location (e.g. in the same building) at the time of the incident, likelihood of exposure is MODERATE;
- If the individual moved towards the incident, likelihood of exposure INCREASES by ONE LEVEL;
- If the individual remained close to the incident for more than 5 minutes, likelihood of exposure INCREASES by ONE LEVEL; and
- If the individual was at the location, but not until 15 minutes or more after the incident, likelihood of exposure DECREASES by ONE LEVEL.

Specific circumstances may require other factors to be taken into account.

F.21 **Prioritisation of people, irradiation incidents**

(EXTERNAL IRRADIATION INCIDENTS) (RADIOLOGICAL TRIAGE TEAM)

The people selected according to Instruction F.9 should be prioritised using the information collected using Instruction F.16, as follows. Five categories are used: LOW, LOW – MODERATE, MODERATE, MODERATE – HIGH, HIGH. Each person should be assigned to one of these categories using information on the distance of closest approach to the source of irradiation, and their best estimate of the time they remained at this location. Figure F2 may be used for this purpose. If a person came into direct contact with the source, the likely magnitude of exposure is HIGH.

F.22 **Selection and prioritisation of people**

(FOOD/WATER CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE TEAM)

Affected individuals must be identified on the basis of information on the likelihood of them having consumed contaminated foodstuffs or water. The location of contaminated food or water may be identified on the basis of intelligence, and/or on the basis of monitoring of foodstuffs/water. Individuals should be prioritised according to the likelihood of them having consumed contaminated foodstuffs or water.

Information F.21

This figure illustrates how exposure category depends on time and distance from a source of gamma radiation. It shows exposure relative to the exposure arising from a residence time of 1 second at a distance of 1 metre from a radiation source. These calculations are approximate and do not take account of the effect of shielding by material (e.g. walls of buildings) between the person and the source.

Time (s)	Distance (m) 1	2	5	10	20	50	100
1	1.00E+00	2.50E-01	4.00E-02	1.00E-02	2.50E-03	4.00E-04	1.00E-04
2	2.00E+00	5.00E-01	8.00E-02	2.00E-02	5.00E-03	8.00E-04	2.00E-04
5	5.00E+00	1.25E+00	2.00E-01	5.00E-02	1.25E-02	2.00E-03	5.00E-04
10	1.00E+01	2.50E+00	4.00E-01	1.00E-01	2.50E-02	4.00E-03	1.00E-03
20	2.00E+01	5.00E+00	8.00E-01	2.00E-01	5.00E-02	8.00E-03	2.00E-03
50	5.00E+01	1.25E+01	2.00E+00	5.00E-01	1.25E-01	2.00E-02	5.00E-03
100	1.00E+02	2.50E+01	4.00E+00	1.00E+00	2.50E-01	4.00E-02	1.00E-02
200	2.00E+02	5.00E+01	8.00E+00	2.00E+00	5.00E-01	8.00E-02	2.00E-02
500	5.00E+02	1.25E+02	2.00E+01	5.00E+00	1.25E+00	2.00E-01	5.00E-02
1000	1.00E+03	2.50E+02	4.00E+01	1.00E+01	2.50E+00	4.00E-01	1.00E-01
2000	2.00E+03	5.00E+02	8.00E+01	2.00E+01	5.00E+00	8.00E-01	2.00E-01
5000	5.00E+03	1.25E+03	2.00E+02	5.00E+01	1.25E+01	2.00E+00	5.00E-01

HIGH exposure category
MODERATE - HIGH exposure category
MODERATE exposure category
MODERATE - LOW exposure category
LOW exposure category

Figure F2. Dependence of exposure category on distance and time.

Information F.22

Monitoring of contaminated foodstuffs/water

This is likely to require a large-scale programme of foodstuffs/water monitoring. Triage based on clinical signs and symptoms [Section F.2.2.2] should also be employed as a supplementary method for identifying the most exposed individuals. It must be accepted that it may not be possible to identify everyone whose health may be affected by the incident.

F.23 **Recommended actions**
Instructions F.24 to F.29 should be carried out for each person selected according to Instructions F.19 or F.9 or F.22, in the order of priority determined according to Instructions F.20 or F.21 or F.22.

F.24 **The next stage of triage**
(RADIOLOGICAL TRIAGE TEAM)
Carry out radiological triage based on clinical signs and symptoms [Section F.2.2.2].

F.25 **Decontamination**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE, DECONTAMINATION TEAMS)
Direct to decontamination facilities if this has not already been done [Chapter G.2].

F.26 **Initial individual contamination monitoring**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)
Carry out initial individual monitoring as described in [Section F.3]. In general, the sequence is: external contamination monitoring; further decontamination (if monitoring indicates that it is necessary); and initial internal contamination monitoring.

F.27 **Internal contamination monitoring**
(FOOD/WATER CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)
Carry out initial individual monitoring for internal contamination as described in Section F.3.4.

F.28 **Advice on decontamination**
(ENVIRONMENTAL CONTAMINATION INCIDENTS)
(RADIOLOGICAL TRIAGE, DECONTAMINATION TEAMS)
If people selected according to Instruction F.19 are sent home without decontamination and without monitoring because of shortage of suitable resources, they should be provided with advice on decontamination [Section G.3].

Information F.23 - F.28
Decontamination should not be delayed in order to carry out monitoring. However, if there is a backlog of people waiting for decontamination facilities to become available, those waiting may be monitored.

F.29 Symptoms of ARS

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

People selected according to Instructions F.19, F.9 or F.22 and who are sent home, must be advised to contact immediately the appropriate authorities if they are suffering from nausea, vomiting or diarrhoea [Section K.7]. These individuals should be interviewed regularly to determine whether they are exhibiting these symptoms [Section F.2.2.2].

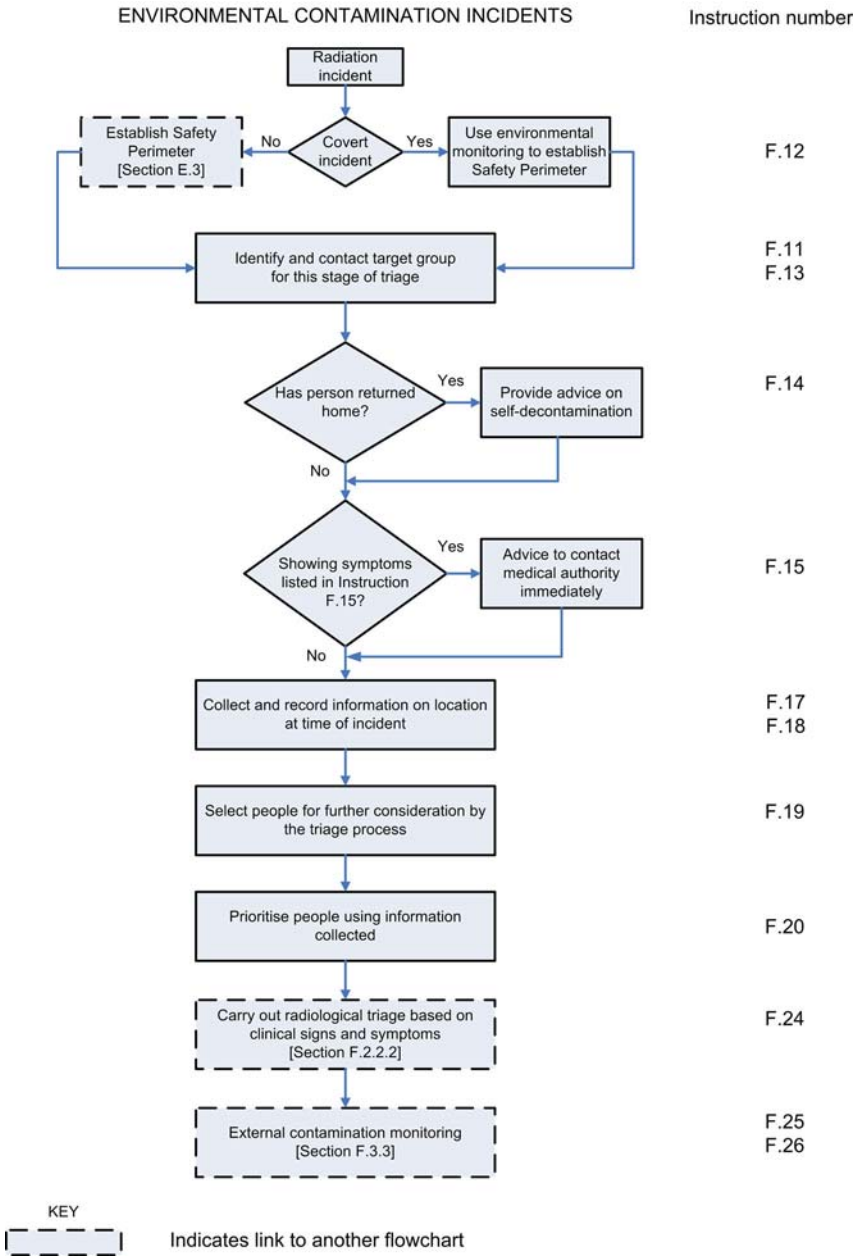


Figure F3. Flowchart for radiological triage based on information on location.

2.2.2 *Triage based on clinical signs and symptoms*

Introduction

Radiological triage based on clinical signs and symptoms is aimed at identifying people who may have received radiation doses that are large enough to cause deterministic effects on health. This section explains how the observation of prodromal (i.e. early onset) symptoms should be used to identify these people. In many cases, symptoms will present themselves within a few hours of acute whole body exposure, but this will not always be the case, and some individuals with exposures at deterministic effect levels may not exhibit observable prodromal symptoms at all. This stage of triage should be treated as a dynamic, rather than a "once only" process; it will be necessary to review at regular intervals the outcomes of this part of the triage process for the individuals of potential concern. This regular review will certainly need to be carried out during the 6-day period covered by the triage procedures described in this chapter, but it will also need to be extended to later phases of the response [Sections J.4 and J.5]. Actions required for this stage of radiological triage are summarised in Figure F6.

F.30 **Target groups for triage**
(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

The three groups of people who must be subjected to triage based on clinical signs and symptoms are:

- All patients in trauma triage categories P2 and P3 (P1 patients would already have been sent to hospital and would be being dealt with on an individual basis);
- All people who were within the Red Zone during or after the incident; and
- Any people for whom individual monitoring and dosimetry indicates that they may receive exposures large enough to cause deterministic effects.

These people must be interviewed to determine whether they have (or are observed to have) the following symptoms:

- Vomiting;
- Nausea;

Information F.30a

Liaison with medical staff

It is very important that procedures are put in place to ensure effective and timely exchange of information between staff with responsibilities for triage and monitoring and medical staff responsible for the care of patients.

Information F.30b

Important information

For uniform whole body irradiation giving doses less than about 1 Gy, the patient will generally not show any symptoms (Goans et al, 2005).

People not suffering from any of the symptoms listed in Instruction F.30 may still have received doses in excess of 1 Gy. Even at 2 Gy, only about 40 % of patients will suffer from vomiting (Dainiak, 2007). Thus, some people exposed at levels that will cause deterministic effects will not be identified as such by this stage of triage.

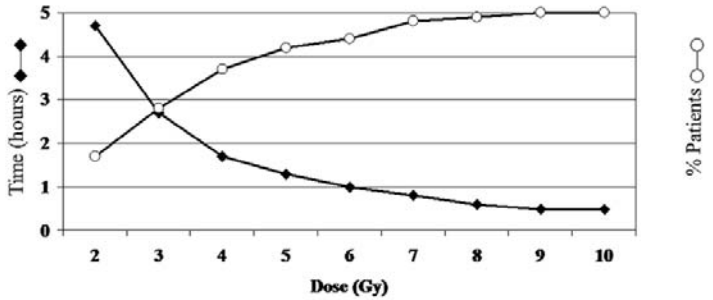


Figure F4. Relationship between time to onset of vomiting and dose over a range of 2-10 Gy. The right hand scale runs from zero to 100 %. Reproduced with kind permission from Nicholas Dainiak (Dainiak, 2007).

Information F.30c

Important information

The initial (prodromal) phase of *acute radiation syndrome* usually occurs in the first 48 hours, but may not develop until 6 days after exposure (Waselenko et al, 2004).

Information F.30d

A caution

Note that many people who report these symptoms will not have been exposed to any significant extent to radiation or radioactive contamination, but may be experiencing the symptoms because of stress and anxiety.

- Diarrhoea; and/or
- Erythema (reddening of the skin).

F.31 **Actions if symptoms of ARS are not observed**
(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)
If the person is not suffering from any of these symptoms, then no further actions are required in this stage of radiological triage. The person must be instructed that they MUST report to an identified health care centre if they develop symptoms such as nausea, vomiting, diarrhoea, skin reddening or blistering. Written instructions with a contact list for these health centres should be provided [Section K.4].

F.32 **Assignment to a radiological triage category**
(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)
Information on time to vomiting and on time to onset of nausea and diarrhoea should be collected from all people suffering from any of the symptoms identified in Instruction F.30. People should be assigned to Radiological Triage Categories I, II or III on the basis of the information collected, according to the scoring system given in the leaflet "European approach for the medical management of mass radiation exposure". The relevant part of the leaflet is reproduced in Information F.32b. Further guidance is given in Annex 5, where the complete leaflet is reproduced.

All those people subjected to radiological triage and not assigned to Categories I, II or III should be assigned to Category 0.

F.33 **Blood cell counts**
(MEDICAL TEAM)
A blood sample should be taken as soon as possible for any persons in Radiological Triage Categories I, II or III, and a complete blood count (CBC) should be carried out urgently. If necessary, call in staff with specialist expertise.

Information F.32a

This categorisation scheme is completely separate from the trauma triage categorisation scheme (i.e. P1, P2 and P3) [Section F.1].

Information F.33

Important information

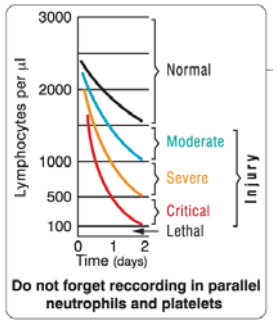


Figure F5. Lymphocyte depletion (EBMT, 2007, courtesy of authors).

For whole body doses exceeding 1 Gy, the lymphocyte blood cell population decreases with increasing dose and increasing time since exposure (Goans and Waselenko, 2005), so measurements of depletion kinetics provide an estimate of dose. This graph shows the concentration of lymphocytes in blood (number of lymphocytes in 1 µl of blood) after an acute whole body exposure.

CBC provides estimates of uniform whole body doses in the range 1 – 10 Gy (Blakely et al, 2005).

Software tools are available to estimate dose from both time to vomiting and from CBC (Blakely, *http://www.afrri.usuhs.mil/www/outreach/biodos-tools.htm#software*).

Additional blood samples
CBC is more accurate when two or more samples are taken so that changes in blood cell counts can be observed directly. It is therefore very important to obtain at least one further blood sample, whenever possible, and to take the initial blood sample as soon as possible.

Further blood samples should be taken after admission to hospital to enable blood cell depletion to be measured. Different approaches have been proposed in terms of numbers and frequency of sampling (Mettler, 2005; Blakely et al, 2005; Daniak et al, 2006). After the first sample, it is recommended to take sequential samples several times within the initial days after exposure in order to calculate the rate of lymphocyte decline. Guidance on blood sampling after admission to hospital is provided in Chapter J [Section J.4, Instructions J.6:3 and J.7:7].

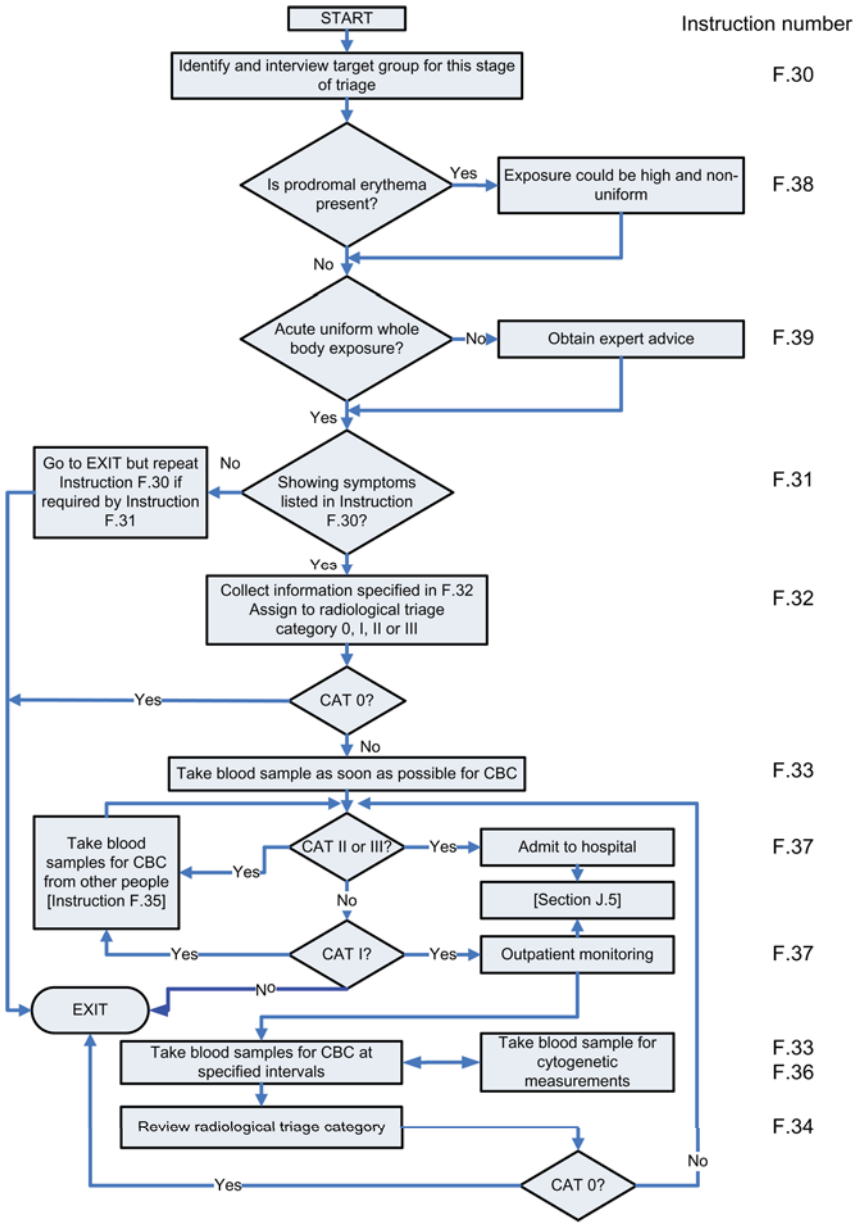


Figure F6. Flowchart for radiological triage based on clinical signs and symptoms.

Information F.32b

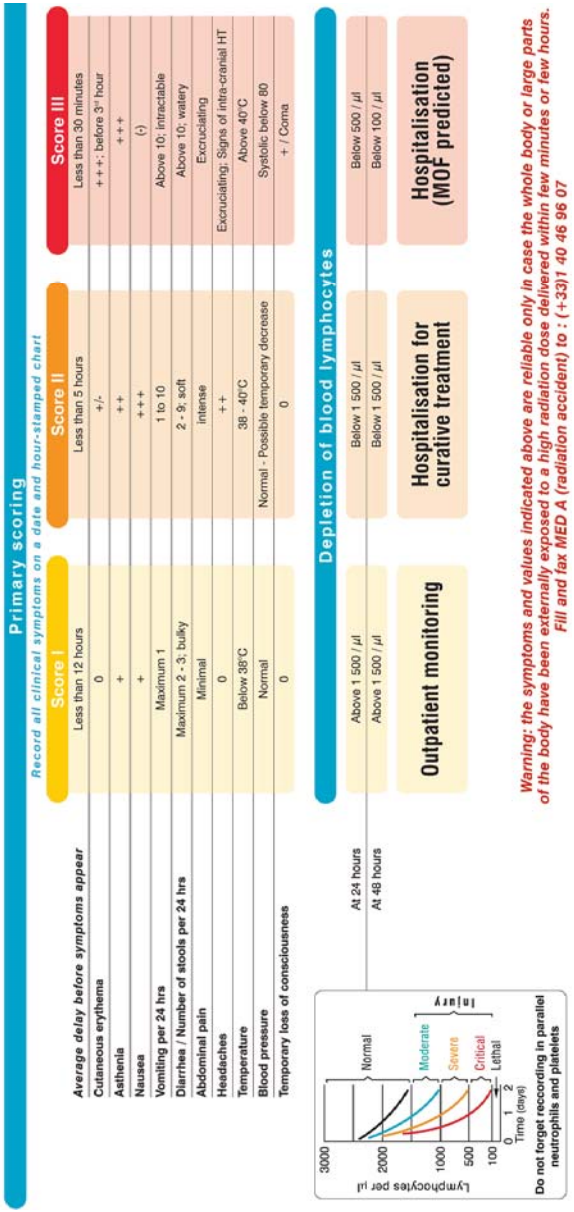


Figure F7. European approach for the medical management of mass radiation exposure. Reproduced from EBMT, 2007, courtesy of authors. The full leaflet is reproduced in Annex 5.

If the person is to be admitted to hospital immediately, the blood sample may be taken there, otherwise the blood sample should be taken at an appropriate location in the field (e.g. at the Public Processing Area in the Yellow Zone).

If admission to hospital is not possible during the first hours, take blood samples at 8 hour intervals on the first day, 12 hour intervals on the second day, and perform blood cell counts. Depending on the results, two further blood samples should be taken during the first week after the incident, depending on the number of people for whom a CBC is required and the available capacity [Section J.4 and Instruction J.6:3].

F.34 **Review of triage assessments**

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

Allocation of individuals to Radiological Triage Categories should be reviewed as soon as the result of each CBC count is available. The graph shown in Information F.33 may be used for an initial evaluation. Any result other than "Normal" should be referred for medical assessment [Section J.4].

F.35 **Extension of blood sampling**

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

If there is any evidence that suggests that doses received by some individuals could be high enough to result in deterministic effects, then blood samples should be taken for a representative number of people assigned to the highest potential exposure category on the basis of information on location [Section F.2.2.1].

If CBCs on these samples indicate significant exposures to any individual, blood sampling should be extended to every person assigned to the highest potential exposure category on the basis of information on location, and to randomly selected people in lower exposure categories. Decisions on people selected for blood sampling should be reviewed as soon as CBC results are available.

F.36 **Chromosome aberration analysis**

(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)

Where CBCs indicate significant exposures, separate blood samples

Information F.35

In the flowchart in Figure F6, actions corresponding to the "Yes" pathway to the right of the decision boxes labelled "CAT I?" and "CAT II or III?" are actions relating to the individual. Actions corresponding to the "Yes" pathway to the left of these boxes are actions relating to groups of other people.

Information F.36a

Chromosome aberration analysis is a more accurate dose assessment method than CBC and is often described as the "gold standard" for individual biodosimetry (Lloyd et al, 2000). However, results are unlikely to be available until 4 to 5 days after the incident [Section J.10].

Information F.36b

Other techniques will also provide supplementary information (e.g. premature chromosome condensation assay, analysis of molecular biomarker analysis, etc.) [Section J.10].

Information F.37a

There is no urgent need for medical intervention for patients in Radiological Triage Categories I, II or III within the first 48 h after acute exposure. The most important need is for patients to be kept under observation by a medical team whose members possess the appropriate expertise [Section J.5].

Information F.37b

In the flowchart in Figure F6, two action paths are identified for people referred for outpatient monitoring. The first path refers to actions relating to general care, which are addressed in Section J.5. The second path refers specifically to further blood sampling, which may need to take place within the context of the field response. Clearly, liaison between field and hospital is needed [Information F.30a].

should be collected for chromosome aberration analysis. Samples should be collected approximately 24 hours after exposure [Section J.10 and Annex 11].

F.37 **Referral to hospital**

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

Patients should be referred to hospital or other medical facility on the basis of their Radiological Triage Category (i.e. I, II or III). The "European approach for the medical management of mass radiation exposure" leaflet [Annex 5] advises on medical treatment [Section J.5]. Table A5.1 in Annex 5 also presents advice on the level of medical response needed for people in these categories.

F.38 **Observation of erythema**

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

If prodromal erythema (reddening of the skin) is observed, this may indicate exposures in excess of about 2 Gy. A blood sample should be collected for CBC. A decision should be made on whether to admit the patient to hospital [Section J.7].

F.39 **Non-uniform exposures, and exposures extended in time**

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

Guidelines given above for the interpretation of information on clinical signs and symptoms apply only to acute whole body exposures (typically where more than 60 % of the body is uniformly irradiated). If exposures are non-uniform or extended in time the guidelines will not be directly applicable. Reference should be made to Section J.5 for guidance, and expert advice should be sought.

F.40 **Internal contaminations and deterministic effects**

(CONTAMINATION INCIDENTS) (RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

Radiation doses resulting from internal contamination are generally received over a protracted period of time and can be either distributed uniformly (e.g. after intake of ^{137}Cs) or very non-uniformly (e.g. after intake of ^{210}Po). Monitoring and assessment of internal dose will provide an important input to triage decisions [Section H.4].

Information F.38a

Important information

Erythema (reddening of the skin) is generally seen within a few hours to a few days after doses to the skin in excess of 2 Gy. Erythema occurring on some part of the skin but not others may be an indicator of high but non-uniform exposure. Other prodromal symptoms may not be exhibited under such circumstances. It is important to ensure that patients are not wrongly excluded on the assumption that the erythema has a different cause (e.g. heat burn, chemical burn, sun burn). On the other hand, erythema should not be attributed immediately to radiation exposure.

Information F.38b

An example of a radiological triage system from a recent emergency exercise

In the event of a real incident, the guidelines on radiological triage given in Section F.2.2 would need to be adapted to the circumstances of the incident and the extent of information available. As noted in the Introduction to Section F.2, different stages of triage would need to be carried out together rather than sequentially. Figure F8 shows an outline of a triage system set up as part of an emergency exercise held in the UK in 2008. This triage system took account of information on both location and observed clinical signs and symptoms. The scenario was the discovery of a highly radioactive ^{137}Cs fragment at a railway station on 28 August, following an explosion at another location on 26 August. The dose rate close to the fragment was of the order of 100 mGy h^{-1}. The aim was to prioritise people for cytogenetic analysis of blood samples; this technique should provide the capability to detect doses from external irradiation above about 100 mGy.

Measures had already been put into place for a medical team to carry out radiological triage assessments for all those who visited the station on or after 26 August and reported nausea, vomiting and diarrhoea. The top priority was therefore to find people who could be suffering from radiation erythema as a result of being in contact with the radioactive fragment. The next priority was to identify people who could have remained close to the fragment for more than 5 minutes. Given that exposure could have taken place up to two days previously, it was presumed that people would not recall how long they remained on the platform with any accuracy. Furthermore, the information available indicated that the radioactive fragment could have been anywhere within the covered section of the platform during the previous two days. (Continued over page).

F.41 **Long-term follow up**

(PEOPLE MONITORING, MEDICAL TEAMS)

People subjected to radiological triage based on clinical signs and symptoms may be considered for long-term health and radiation protection follow up [Section K.9].

Information F.38b (cont.)

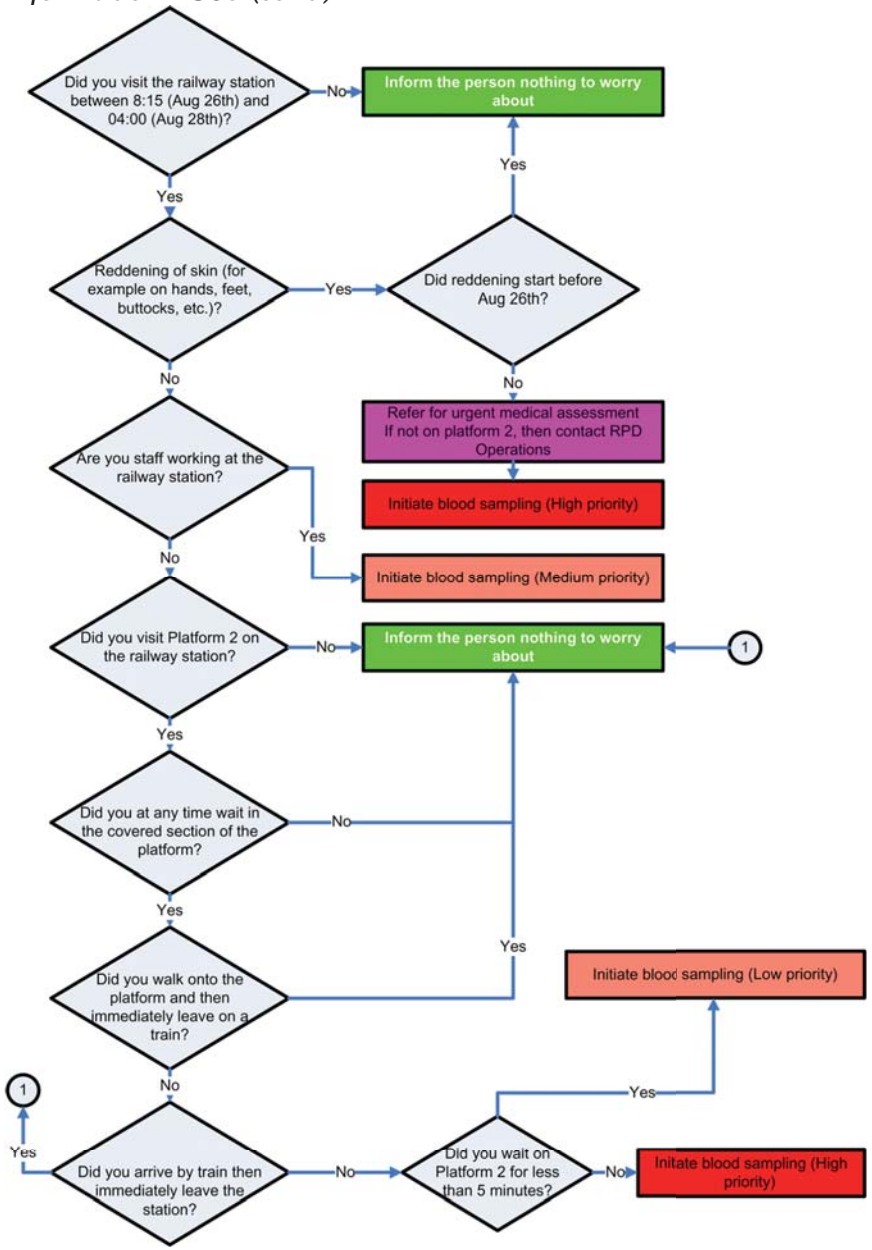


Figure F8. An outline of a radiological triage system.

3 Initial monitoring

Introduction

In the initial stages of the response, a number of different types of monitoring are needed:

1. Monitoring of *environmental gamma dose* rates within the affected areas (required for both external irradiation incidents and environmental contamination incidents). Results will allow doses received from external irradiation to be estimated for individuals who were within (or remain within) the affected areas. This monitoring will enable decisions to be made to remove any remaining people from areas with high dose rates and to restrict access to these areas. It will also help to confirm that zone boundaries have been correctly located (or will indicate where changes to zone boundaries are needed).
2. Monitoring of *environmental contamination levels* within the affected areas (required for any environmental contamination incident). Monitoring will provide information on the spread of environmental contamination, and will help in the control of exposure to internal contamination. Contamination monitoring provides another important input to decisions about the placement of zone boundaries.
3. Monitoring of *external contamination levels on people* (required for any environmental contamination incident). Results will enable decisions to be made on the need for decontamination of people, which is usually the simplest and most effective means for reducing individual doses in the early stages. Monitoring will enable people who could potentially have contamination levels high enough to cause deterministic effects to be identified quickly and directed for medical assessment. Results would also be used to prioritise people for internal contamination monitoring. The rapid initial screening will enable decisions to be made on which type of further monitoring, if any, would have to be carried out.

4. Monitoring of *internal contamination* levels in people (required for any environmental contamination incident and for any incident involving contamination of food/water). Monitoring will enable people who could potentially have internal contamination levels high enough to cause deterministic effects to be identified quickly and directed for medical assessment. Results will enable decisions to be made on the need for treatment to reduce internal doses (e.g. with Prussian Blue to reduce levels of Cs in the body [Instruction J.24]). Taken together with estimates made of external doses to individuals, this monitoring will also help to establish the magnitude of stochastic risks to health.

This section details the procedures necessary for carrying out this monitoring, and includes practical advice on monitoring for different types of radiation.

In general, initial monitoring can be carried out using appropriate hand held radiation monitors [Annex 2]. Radiation monitoring is a specialised task that must be carried out by trained staff [Annex 4]. Emergency services personnel who are quickly on the scene may have the skills necessary to carry out the less specialised monitoring tasks (e.g. of environmental gamma dose rates), but staff with the skills necessary to carry out all the required monitoring tasks will take some time to arrive. It is very important that adequate records are kept of the results of monitoring [Section H.6 and Annex 3].

Guidelines on limiting exposure of monitoring teams are given in Section E.1.

3.1 Preparatory actions for monitoring teams

F.42 **Despatch to incident location**

(TACTICAL INCIDENT COMMAND [TIC], ENVIRONMENTAL MONITORING TEAM, RECORDS TEAM)

Before leaving for the incident site the monitoring team(s) must be informed of the location of the Marshalling Area [Section E.3] and the most direct route to take to get there, avoiding the incident and associated traffic.

F.43 **Equipment**

(ENVIRONMENTAL MONITORING TEAM)

The monitoring team(s) must confirm that all required equipment is in good working order, with fully charged batteries, and calibrated against a check source. Details of the equipment, check source results and local background levels should be recorded [Annex 3]. If possible the equipment should be prepared for use in a hostile environment [Information F.43]. Each team should have cans of spray paint to physically mark monitored locations, and individual portable Global Positioning System (GPS) equipment.

F.44 **PPE and communications**

(ENVIRONMENTAL MONITORING TEAM)

Each member of the monitoring team must have appropriate PPE comprising of [Section E.1 and Annex 2]:

- Full face respirator;
- Gloves;
- Waterproof clothing (all skin and hair must be covered);
- Waterproof shoes or boots;
- Safety helmet; and
- Alarming dosemeter (measuring instantaneous dose rate as well as cumulative dose).

Alternative PPE giving a similar level of protection may be used. Each team member should also have a reliable means of two-way communication with the control centre (note that mobile phone networks may not be reliable), for example VHF radios.

Information F.43

Dose meters, gamma probes and rate meters can be enclosed in plastic film to protect them from becoming contaminated, as can the handles on alpha and beta probes. The detection surfaces (Mylar screen) on alpha and beta probes must not be covered as this will seriously impair their performance.

Information F.44

It is assumed that each monitoring team will be prepared to carry out any of the monitoring tasks described in the Introduction.

F.45 **Initial briefing and instructions on control of exposure**

(TIC, ENVIRONMENTAL MONITORING TEAM)

On arrival at the incident site, the monitoring team should inform Tactical Incident Command (TIC) of their arrival. TIC must fully brief the monitoring team on the incident, the type of radiation present and provide clear instructions about acceptable/unacceptable levels of exposure, permissible occupancy times and turn-back limits [Section E.1]. The monitoring team should be familiar with the equipment to be used and its response efficiency [Information F.45].

F.46 **Monitoring Control responsibilities**

(TIC, RECORDS TEAM)

TIC should establish a Monitoring Controller, a Monitoring Control Team and a Records Team to perform the following functions:

- Select specific locations to be monitored;
- Prioritise monitoring locations;
- Establish a safe route to a location for a monitoring team;
- Deploy monitoring team(s) to the required locations;
- Maintain and regularly update levels of cumulative dose for all members of the monitoring teams [Section E.1 and Annex 3].
- Maintain records of the monitoring team(s) deployment and levels of contamination and dose rate found at monitored locations;
- Maintain contact with the monitoring team(s); and
- Relay results and liaise with TIC.

F.47 **Maps, GPS and report forms**

(TIC, ENVIRONMENTAL MONITORING TEAM, RECORDS TEAM)

The monitoring team should be provided with adequate maps of the area, hand-held GPS units if possible, and appropriate report forms [Annex 3].

F.48 **Monitoring instruments**

(ENVIRONMENTAL MONITORING TEAM)

If the type of radiation (e.g. alpha (α), beta (β), gamma (γ) or neutron) has been identified, then only the equipment required to

Information F.45

Contamination monitoring equipment display activities as counts per second or cps and not Bq cm^{-2}. Conversion from cps to Bq cm^{-2} requires the response efficiency to be known, and this is instrument-specific (although similar equipment will have similar efficiencies and so a generic value may be applied). The monitoring team may be more familiar with cps and prefer to use these units. If so, they should convert the values (and double check the calculations) before starting monitoring. Reported results must include the reading, the units in which the result is expressed, the type of instrument and the conversion factor for the instrument. Record the conversion factor on the instrument with a waterproof marker pen.

detect that type of radiation need be deployed. Annex 2 and Annex 8 specify recommended monitoring equipment.

F.49 **Expertise**
(ENVIRONMENTAL MONITORING TEAM)
If alpha (α) or beta (β) radiation has been identified, then TIC must ensure that all monitoring teams are proficient in detecting this type of radiation [Information F.49].

F.50 **Monitoring in the Marshalling Area**
(ENVIRONMENTAL MONITORING TEAM)
Wearing PPE, the monitoring team should switch ON (and leave on) the monitoring equipment and obtain and record representative background values at the Marshalling Area. The dose rates or contamination levels should not exceed those for the Security Perimeter [Table F2, Information F.56]. If any of these values are exceeded, then TIC must be informed immediately and a new location considered.

3.2 Environmental monitoring

F.51 **Establishing monitoring priorities**
(TIC, ENVIRONMENTAL MONITORING TEAM)
Priorities should be established from a consideration of the circumstances of the incident. Monitoring tasks are likely to include some or all of the following:

- Monitor along the Safety Perimeter to confirm it is safely positioned;
- Perform a rapid area survey within the Safety Perimeter to determine whether the area enclosed within it (the Red Zone) can be reduced;
- Perform a rapid area survey within the Red Zone, close to the incident location to identify any areas of high gamma dose rate (Sv h^{-1} or Gy h^{-1}) or contamination (Bq cm^{-2} or Bq m^{-2});
- Perform a rapid area survey of the Yellow Zone to confirm that no ‘hot spots’ are present, doses to emergency services personnel and other personnel responding to the incident remain with

Information F.49

Due to the short range of alpha and beta particles in air, when monitoring for this type of radiation the probe should be as close as possible, and no further than 1 cm, from the surface being monitored. The contaminated surface must be dry and should be traversed at a rate of 10 cm per second or slower.

Particular care is required when monitoring for alpha and/or beta radiation to avoid puncturing the detection surface (Mylar screen) of the probe and making the instrument light sensitive. The extent of the damage can result in readings ranging from enhanced background to full scale deflection. Damaged probes should be replaced.

Information F.50

Initially the positioning of the Security Perimeter will be based on criteria other than monitoring data. This will probably be the first opportunity to confirm that the area completely encompasses the Red Zone and is radiologically "safe".

Figure F9. Alpha contamination monitoring. This photograph illustrates the method, but when responding to an incident, additional measures would need to be employed, i.e. the detector would be wrapped in plastic film with the exception of the front window. Photos: STUK.

acceptable limits, and doses to members of the public temporarily remaining in the Yellow Zone remain within acceptable limits;

- Perform a detailed area survey of the Red Zone, when resources become available; and/or
- Perform a detailed area survey of the Yellow Zone, when resources become available.

F.52 Specifying tasks for the Monitoring Teams

(ENVIRONMENTAL MONITORING TEAM)

Each monitoring task should be reduced to a set of simple instructions to be provided to a monitoring team. This task plan should specify the locations to be monitored and the type of measurements to be performed (e.g. gamma dose rate, contamination with beta-emitters, contamination with alpha emitters, etc). An example of a simple task plan for gamma dose rate monitoring around a boundary is given in Information F.52. For an area survey, the monitoring team should be requested to monitor at the intersection points on a suitably spaced grid.

F.53 Initiating the monitoring task

(ENVIRONMENTAL MONITORING TEAM, TIC)

From a previously confirmed 'safe' location, the monitoring team should advise Monitoring Control when they are ready to proceed and await instructions. Monitoring Control should then issue a task plan to the Monitoring Team. TIC must confirm, via Monitoring Control, that it is safe for the monitoring team to proceed.

F.54 Recording and Reporting

(ENVIRONMENTAL MONITORING TEAM)

Monitored positions and corresponding monitoring data (as requested in the task plan) should be recorded on an appropriate report form [Form A3.1, Annex 3], and provided to Monitoring Control.

Information F.52

Example of a "Task Sheet" for monitoring within the Red Zone

1. Commence gamma dose rate measurements immediately on leaving the Marshalling Area, and proceed via the Secure Access Control Point (SACP) to map grid reference SU 4730 8650.
2. While proceeding along the path at walking pace, record position and gamma dose rate (mGy h^{-1}) at 10 m intervals.
3. Proceed 200 m south (compass heading 183°) to map grid reference SU 4730 8630.
4. Then proceed 200 m east (93°) to map grid reference SU 4750 8630.
5. Then proceed 280 m north-west (318°), returning to map grid reference SU 4730 8650.
6. Return and report to the Monitoring Control Team at the TCP.
7. If a dose rate in excess of x mGy h^{-1} is recorded at any point, report reading immediately to Monitoring Control and then follow the instructions issued.
8. At all times, comply with the "turn back" guidance provided separately [Information E.5, Table E2].

F.55 **Control of exposure**

(ENVIRONMENTAL MONITORING TEAM)

While proceeding to a specified location, the monitoring team must comply with turn-back guidance [Table E2, Information E.5], and ensure that they do not enter into a high dose or contaminated area. Rapid measurements, particularly gamma dose rates, must be taken at regular intervals (for example at 5 to 10 metre intervals). Team members should report their individual cumultative dose readings to Monitoring Control at regular intervals.

F.56 **Monitoring the Safety Perimeter**

(ENVIRONMENTAL MONITORING TEAM, RECORDS TEAM, TIC)

A minimum of 8 regularly spaced locations on the Safety Perimeter must be monitored to confirm that the Safety Perimeter is safely positioned.

If the dose rates or contamination levels exceed those for the Safety Perimeter [Table F2], then the monitoring team must perform a more detailed survey to confirm whether the high dose rate or contamination is widespread or a "hot spot" [Section E.2].

If the high levels are widespread, the monitoring team must physically mark the location and record results before retreating to their previous (rapidly monitored) location (5 to 10 metres back). There they must rapidly confirm that dose rates and contamination levels are within limits [Table F2] and report their findings to Monitoring Control. They must then perform a detailed survey of their present location and report the result, plus the current cumulative dose for each member of the monitoring team, to Monitoring Control. Monitoring Control must liaise with TIC who must consider relocating the Safety Perimeter.

If the high dose rate or contamination is a "hotspot", the monitoring team must physically mark the location, record the results and report their findings to Monitoring Control.

F.57 **Reducing the size of the Red Zone**

(ENVIRONMENTAL MONITORING TEAM, TIC)

If 4 or more monitoring teams are available, then monitoring should be undertaken to determine whether the size of the Red Zone can be

Information F.56

Table F2. Maximum acceptable contamination levels and dose rates at Safety Perimeter for α–, β–, and γ –emitters.

Perimeter	*Type of measurement*	*Measured value must not exceed*
Red Zone (Safety)	Alpha contamination level	100 Bq cm^{-2}
	Beta contamination level	1000 Bq cm^{-2}
	Gamma contamination level	1000 Bq cm^{-2}
	Gamma dose rate	100 μSv h^{-1}

(IAEA EPR-First responders, 2006).

Information F.57

Initially the Safety Perimeter will be established at a radius of 400 m surrounding the incident. At this distance, the Safety Perimeter extends for more than 2500 metres, enclosing an area greater than 500 000 m^2, and will require considerable resources to maintain. Ideally the area of the Red Zone should be reduced as soon as practicable.

reduced [Information F.57]. On completion of Instruction F.56, Monitoring Control should deploy each monitoring team to different points on the Safety Perimeter where ALL the dose rate and contamination values are less than the Safety Perimeter values [Table F2]. Then, each monitoring team should move towards the centre of the Red Zone until they detect a dose rate or a contamination level equivalent to a Safety Perimeter value [Table F2]. The results should be reported to Monitoring Control who should relay them to the TIC. TIC should consider relocation of the Safety Perimeter.

F.58 **Rapid area survey within the Red Zone**

(ENVIRONMENTAL MONITORING TEAM)

Monitoring Control should review existing environmental monitoring data for the Red Zone, and then specify map references for a grid of points at which area survey monitoring is to be carried out. A higher priority should be given to monitoring areas where casualties and emergency services personnel are (or were) located [Information F.58].

Team members should ensure they are aware of the guidelines on control of exposure [Section E.1], and in particular:

- The emergency worker turn-back guidance [Table E2, Information E.5]; and
- Operational Intervention Levels (OILs) [Table E3, Information E.8] (which apply when gamma dose rate is known).

F.59 **Control of exposure**

(ENVIRONMENTAL MONITORING TEAM)

If the dose rates exceed 100 mSv/h, then the monitoring team must immediately stop, mark the location, retreat to the previous ‘safe’ location (5 to 10 metres back), and record the result. There they should confirm that dose rates are below 100 mSv/h and then inform Monitoring Control, who should record the results of the monitoring plus the cumulative dose of each member of the team. Monitoring Control should then provide an alternative route for the monitoring team.

Monitoring Control must consider withdrawing monitoring teams if accumulated dose to an individual arising from the incident could exceed 50 mSv.

Information F.58

Monitoring Control should divide areas requiring monitoring into sections using physical features such as roads, rivers and buildings where possible.

The monitoring team may well decide to further subdivide each section for monitoring using other physical features such house numbers, trees and drain covers.

F.60 **Rapid area survey within the Yellow Zone**
(ENVIRONMENTAL MONITORING TEAM)
Monitoring Control should review any existing environmental monitoring data for the Yellow Zone, and then specify map references for a grid of points at which area survey monitoring is to be carried out. Priority should be given to areas occupied by emergency services personnel and other personnel responding to the incident, and to areas being used to process members of the public.

3.3 Monitoring people for external contamination

F.61 **Working with contaminated people**
(PEOPLE MONITORING TEAM)
The presence of radioactive material, in any quantity, on people should not prevent trained personnel wearing PPE from monitoring them.

F.62 **Planning**
(PEOPLE MONITORING TEAM)
Monitoring Control should decide the monitoring procedures to be adopted taking into account the following:

- Severity of any injuries to people requiring monitoring;
- Number of people requiring monitoring;
- Availability of decontamination facilities; and
- Availability of monitoring facilities.

F.63 **Transfer of Category P1 patients to hospital**
(FIRST RESPONDERS)
Casualties designated as P1 must be dispatched immediately to hospital and will not be monitored [Section F.2.1]. Personnel transporting a P1 casualty to hospital must be informed and must inform hospital staff that the casualty has not been decontaminated [Chapter I].

F.64 **Decontamination and monitoring of category P2 patients**
(FIRST RESPONDERS, PEOPLE MONITORING TEAM, RECORDS TEAM)
Casualties designated as P2 should be decontaminated and if

possible monitored and the results recorded before going to hospital [Section F.2.1]. These people may need to be moved to be monitored. This should be performed by medical personnel.

F.65 **Decontamination and monitoring of category P3 patients**
(PEOPLE MONITORING TEAM, RECORDS TEAM)
Casualties designated as P3 should be decontaminated, and if possible monitored, and the results recorded before going to a medical facility [Section F.2.1]. These people may need to be moved to be monitored. Some P3 casualties may be advised to return home after being provided with advice on self-decontamination [Section G.3], with instructions to return to a medical facility at a later time.

F.66 **Monitoring people from the Red and Yellow Zones**
(PEOPLE MONITORING TEAM)
Uninjured people who have been in the Red Zone should be monitored and, if possible, decontaminated.

Uninjured people who have been in the Yellow Zone, but not the Red Zone, should be monitored if resources allow.

F.67 **Monitoring emergency services personnel**
(PEOPLE MONITORING TEAM)
All emergency services personnel must be monitored, and decontaminated if necessary, at the end of their period of duty.

F.68 **Monitoring procedures**
(PEOPLE MONITORING TEAM, RECORDS TEAM)
The monitoring undertaken could take place in the Public Processing Areas [Section E.3] and will depend on resources available and the number of people to be monitored. Priority must be given to those considered to be the most potentially contaminated. Results and personal information should be recorded for each person monitored [Annex 3].

Any monitoring procedure adopted should aim to monitor and identify all potentially contaminated people within 10 hours of the incident occurring as the last person to be monitored may be the most contaminated.

In the event that the number of potentially contaminated people greatly exceeds the monitoring resource available, then the monitoring approach must be adapted to screen people and identify those most contaminated. Faster monitoring times, with consequential loss in monitoring sensitivity, and the setting of higher action level values should be considered.

Each monitoring team should consist of a monitoring officer and a clerk to record results.

F.69 **Use of portal monitors**

(PEOPLE MONITORING TEAM)

A portal monitor is specialist monitoring equipment, capable of monitoring more than 150 people per hour, that should be used, if available, to categorise potentially contaminated people when:

- The contamination includes only beta/gamma emitters (or the isotope ratios of beta/gamma emitters to alpha emitters or pure beta emitters is known). Portal monitors will not detect the presence of pure beta or alpha contamination;
- The number of potentially contaminated people requiring monitoring greatly exceeds other monitoring resources (either personnel or equipment); and/or
- High action level values are permissible (portal monitors are of limited sensitivity particularly at gamma energies below 200 keV).

F.70 **Screening survey**

(PEOPLE MONITORING TEAM)

Using the method described in Information F.70, each monitoring team, using hand held instruments, could monitor up to about 20 people per hour. This approach should be considered if:

- Portal monitors are not available; or
- Alpha contamination is present (this will considerably reduce the throughput of people).

To attain the 10 hour target for indentifying contaminated people, there should be no more than 200 people allocated to each monitoring team.

Figure F10. Monitoring people for external contamination. Photo: HPA.

Information F.70

Screening survey

Holding the survey meter probe about 2-5 cm (for alpha monitoring about 1 cm) away from the body, slowly move the probe at about 5 cm per second over the areas to be monitored. Do NOT touch any potentially contaminated surfaces. Pause the probe for about five seconds at locations most likely to be contaminated and areas identified as contaminated. The following areas must be monitored:

- Start with the face, top and sides of head (pause at mouth and nose for approximately five seconds (high readings may indicate internal contamination);
- Front of the neck and shoulders;
- Right hand – palm and back (pause at palm for about five seconds);
- Left hand – palm and back (pause at palm for about five seconds); and
- Back of the neck and shoulders.

F.71 **Entire body scan**

(PEOPLE MONITORING TEAM)

Using the method described in Information F.71, entire body scans require considerable monitoring resources (personnel and hand held instruments). Up to 10 people can be monitored per hour per monitoring team. This approach should be considered if:

- Portal monitors are not available;
- Alpha contamination is present (this will considerably reduce the throughput of people to about 5 per hour); and/or
- Lower action levels or more precise monitoring is required.

To attain the 10 hour target there should be no more than 100 people allocated to each monitoring team.

F.72 **Recording results**

(PEOPLE MONITORING TEAM, RECORDS TEAM)

The data recorded should include the type of survey (portal monitor, screen survey, entire body), the average contamination activity and any high activity values for each type of radiation monitored on the diagram provided on the Contamination Survey Sheet [Form A3.4, Annex 3].

F.73 **Comparing measured levels (M) to Action Levels (AL)**

(PEOPLE MONITORING, RADIOLOGICAL TRIAGE, DECONTAMINATION, MEDICAL TEAMS)

Results of external contamination monitoring should be interpreted using the procedures described in Figure F12. Measured levels of external contamination should be compared with Action Levels given in Annex 10. The procedures are described and explained in more detail in Section H.4.2.

F.74 **Actions based on measured levels vs. Action Levels**

(PEOPLE MONITORING, RADIOLOGICAL TRIAGE, DECONTAMINATION, MEDICAL TEAMS)

On the basis of the comparison of measured levels with Action Levels [Annex 10], the actions specified in Table F3 should be carried out.

Information F.71

Entire body scan (see diagram below)

Holding the survey meter probe about 1 cm away from the body, slowly move the probe at 3-5 cm per second over the areas to be monitored. Do NOT touch any potentially contaminated surfaces. Pause the probe for about five seconds at locations most likely to be contaminated and areas identified as contaminated.

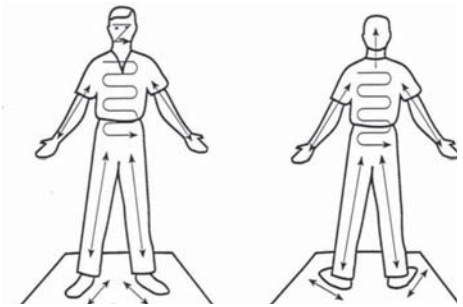


Figure F11. Entire body scan. Reproduced courtesy of IAEA (IAEA EPR-Medical/T, 2002).

To begin a body survey, the individual to be monitored should stand with their legs spread and arms extended, as shown in the diagram with palms facing forward. A consistent procedure should be followed to ensure all the following areas of the body are monitored (see figure above):

- Top and sides of head, face (pause at mouth and nose for approximately five seconds; high readings may indicate internal contamination);
- Front of the neck and shoulders;
- Down front of one arm (pause at palms for about five seconds) and back up the outside;
- Repeat for other arm;
- Across trunk working from shoulders downwards;
- Down front of one leg, over top of foot (pause for about five seconds) and back up the inside of the foot and leg;
- Repeat for other leg and foot;
- Back of head;
- Back of the neck and shoulders;
- Down back of one arm (pausing at elbow), and back up the inside;
- Side of trunk;
- Repeat for other arm and side of trunk;
- Across back working from shoulders downwards;
- Down back of one leg, monitor sole of shoe (pause for about five seconds) and back up the outside of the foot and leg; and
- Repeat for other leg and foot.

NOTE: P2 casualties should only be moved during monitoring by medically qualified staff.

Information F.73

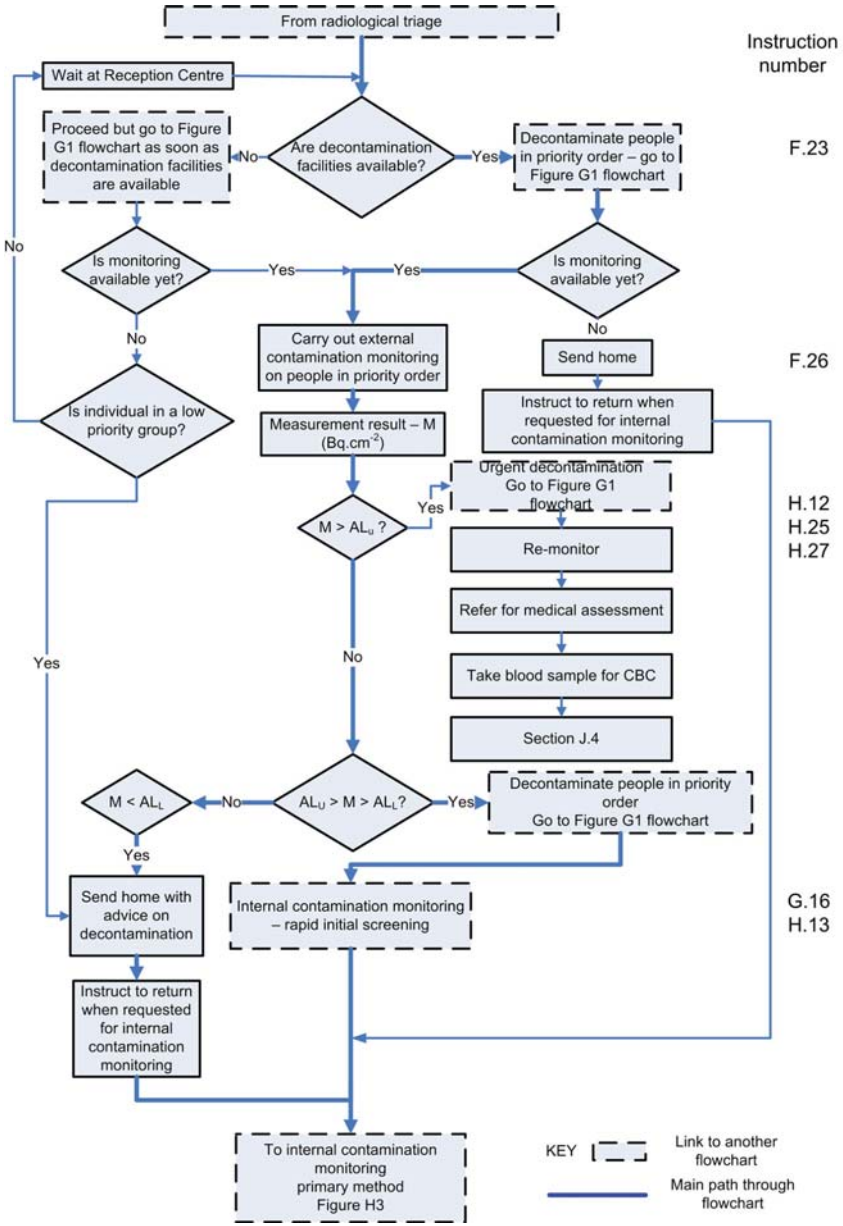


Figure F12. Recommended procedures for external contamination monitoring (also presented in Figure H2 [Section H.4.2] with explanatory text).

Information F.74

Table F3. Actions corresponding to the action levels of Annex 10 (also presented in Table H4 [Section H.4.1] with explanatory text).

Action level on:	Measure-ment, M	Actions
External contami-nation	$M > AL_U$	1. Remove contaminated clothing immediately. 2. Carry out urgent decontamination followed by re-monitoring [Section G.2]. 3. Commence blood sampling for CBC. 4. Refer individual immediately for medical assessment [Section J.4].
	$AL_U > M > AL_L$	5. Carry out decontamination procedures on individuals in priority order [Section G.2].
	$AL_U > M > AL_L$	6. Include in any programme of long-term follow up monitoring [Section K.9]. Carry out rapid initial screening for internal contamination, in priority order.
	$M < AL_L$	7. Instruct individuals to return home and carry out simple decontamination procedures there [Section G.3].
	All measure-ment values	8. Provide information to individual on measured external contamination levels and any associated dose and risk assessments[1] [Annex 3 and Chapter D].
Internal contamina-tion -rapid initial screening	$M > AL_U$	9. Carry out measurements with primary monitoring method urgently. 10. Refer for medical assessment [Section J.4]. 11. Commence blood sampling for CBC and cytogenetic measurements.
	$AL_U > M > AL_L$	12. Carry out measurements with primary monitoring method in priority order.
	$M < AL_L$	13. Consider for inclusion in any programme of long-term follow up monitoring [Section K.9].
	All measure-ment values	14. Provide information to individual on measured internal contamination levels and associated dose and risk assessments[1] [Annex 3 and Chapter D].
Internal contamina-tion -primary monitoring method	$M > AL_U$	15. Refer for medical assessment [Section J.4]. 16. Commence blood sampling for CBC and cytogenetic measurements if not already started.
	$AL_U > M > AL_L$	17. Include in any programme of long-term follow up monitoring [Section K.9].
	$M < AL_U$	18. Consider for inclusion in any programme of long-term follow up monitoring [Section K.9].
	All measure-ment values	19. Provide information to individual on measured internal contamination levels and associated dose and risk assessments[1] [Annex 3 and Chapter D].

Notes.
1. Information provided will depend on the Action Level band in which the measurement value falls.

3.4 Monitoring people for internal contamination

Introduction

After incidents which result only in external exposure to radiation, no contamination monitoring of people is needed. In case of suspected internal contamination, screening should be done. The purpose of the initial screening, with field survey equipment, is to classify people according to their levels of internal contamination as a guide to decisions on further action. The preliminary screening and classification should be performed in an area appropriate to the potential demand, and large enough to permit adequate separation of people awaiting initial monitoring, being monitored, and awaiting transfer for further assessment. Space for temporary collection and storage of contaminated clothing should also be available. A tented area in the Yellow Zone, or public facilities such as sports centres and arenas, are likely to be suitable if a large group of people has to be handled. For a small group, a basement or cellar close to the incident area can be used. The availability of showering and/or washing facilities and good exit route for those sent home would be an advantage.

3.4.1 In vivo monitoring

(CONTAMINATION INCIDENTS)

F.75 **Choice of measurement area**

(PEOPLE MONITORING TEAM)

Establish availability of equipment and facilities for monitoring. Choose a closed (or tented) area large enough to permit adequate separation of people awaiting initial monitoring; being monitored; awaiting transfer for further assessment; and also large enough to permit for temporary collection and storage of contaminated clothing and other belongings.

F.76 **Extra external screening**

(PEOPLE MONITORING TEAM)

If the external contamination monitoring shows upper body contamination, perform another external screening survey after removing outer clothing.

Information Section 3.4.1

Body measurements

Rapid measurements of activity in the bodies of people possibly internally contaminated are needed to separate people not contaminated from those contaminated.

Direct measurements methods for internal contamination that can be conducted close to the scene during the first 48 hours are:

- Measurements with dose rate monitors;
- Whole-body measurements with hand-held scintillation probes;
- Thyroid measurements with hand-held scintillation probes;
- Portal monitors; and
- Portable or transportable body monitors.

Such monitoring equipment should be efficiency-calibrated in advance to be ready to use in case of emergency. If more than one device is available the devices should be checked against each other. The calibration efficiency should be checked once a year or according to local quality assurance procedures for example for ^{60}Co, ^{131}I and ^{137}Cs [Annex 8].

Information F.75

Location of facilities

The environmental background is often highly variable and must be taken into account in data analysis. The measurement technique should be quick and convenient, to ensure cooperation and to avoid anxiety among those monitored. The monitoring equipment should be sited where the levels of natural background radiation are not unusually high, and where levels have not been unduly enhanced by contamination from the incident. The monitoring facilities needed to carry out the actions illustrated in the flowchart [Figure F15] do not necessarily have to be located in the same building or perhaps not even in the same area of a town or city [Figure F12].

A major consideration is to remove external contamination to prevent further internal contamination of the people being measured and to reduce errors in assessment of the internal contamination. The equipment should be used with due regard to the possibility of errors resulting from external contamination (IAEA TECDOC 746, 1994, Section 3.2), either of the subject or of the immediate environment. The background response of the instrument should be recorded both prior to, and periodically during, the daily monitoring programme.

F.77 First steps in monitoring for internal contamination

(PEOPLE MONITORING TEAM)

1. Staff should be dressed in disposable coveralls and gloves. Provide also disposable gloves if there are no facilities for washing hands.
2. People coming for internal contamination monitoring should have been decontaminated. If this has not been done then they should at least remove their outer clothing and shoes. Storage facilities for contaminated clothes and shoes should be prepared.
3. Separate from all others those persons with upper body contamination, particularly the shoulder, head and hair. Assume that a person is not likely to have received a significant internal dose from inhalation without presenting gross external contamination at triage. These persons are the most likely to be internally contaminated. Assume that individuals with contamination only on lower portion of the body crossed the contaminated zone, but were not exposed to the passing plume and did not inhale high airborne radioactivity concentrations. People with significant upper body contamination may require evaluation for follow up medical treatment because they may have inhaled excess amounts of radioactive material (Musolino & Harper, 2006). In case of oral intake via contaminated food or drink the instructions below are also valid.
4. In case of radioiodine contamination thyroid measurements should be made [Instruction F.80]. Portal monitors as well as portable or transportable body monitors would be useful for body counting if accessible [Instruction F.69]. Information on measurement sensitivities are given in Annex 8, Tables A8.1, A8.2 and A8.3.

F.78 Monitoring with dose rate instruments

(PEOPLE MONITORING TEAM)

The initial survey can be done with hand-held scintillation probes or dose rate monitors without any knowledge of the radionuclides involved. Responders arriving at the scene from elsewhere could be used as assumed uncontaminated background reference persons.

Information F.77

Control of surface contamination

Account must be taken for monitoring procedures, particularly in the initial screening, of the possibility of spurious assessments because subjects have imported loose surface contamination, and precautions are required to ensure ready removal of such contamination if it occurs [Information G.2]. The initial screening should take place in an enclosed (or at least tented area) with replaceable surfaces, which subjects would enter after removal of shoes. The monitoring probe should be protected from contamination and staff should wear disposable clothing. The discarded clothing should itself be monitored, and if found to be unacceptably contaminated for further everyday use, it should be put in plastic bags and held in a separate, designated area pending disposal. Clothing contaminated at lower levels, may need to be withheld from subjects referred for more rigorous assessment.

Handling of people to be measured

Remember that it is important to handle the persons coming for measurement calmly and kindly. They are probably more concerned than you. Don't show your worry, don't talk too much, concentrate on what you are doing and explain briefly why. Bear in mind this might be the first opportunity the subject has had to talk to someone. Make sure the teams are well briefed and are aware of where more information can be found [Section F.4 and Section K.8] .

Keep in mind the risk of contamination; avoid contamination of floors, seating places, and instruments. Use common sense in the strange environment.

Especially with a large group of people, 100 persons or more, waiting to be measured a standing position or a geometry with the subject sitting in a chair and the monitoring team member doing the measurement holding the dose rate instrument should be adopted:

1. Choose a suitable area for the monitoring with as low background radiation as possible.
2. Prepare the monitoring equipment. Ensure that the person monitoring is familiar with the instrument.
3. Register the person to be monitored (example registry form in Annex 3).
4. Cover the instrument and the chair with uncontaminated plastic or other material that can be easily changed between each measurement.
5. Start the measurement, record the result and fill in the registry form.
6. Do a background measurement on a non-contaminated person, if possible.
7. Advise the monitored person on suitable follow up actions.

F.79 **Whole-body measurements of high energy gamma emitters with simple equipment**

(PEOPLE MONITORING TEAM)

The measurement geometry used could be the so-called lap geometry if the number of persons to be monitored is limited to less than 100 people. If there is a large group of people awaiting measurement, a standing or sitting position should be adopted with the person doing the measurement holding the detector:

1. Choose a suitable area for the monitoring with as low a level of background radiation as possible. If this is not possible outdoors try a building with high shielding factor, a basement or cellar. The facility should be large enough to make it possible to arrange separate waiting and monitoring rooms.
2. Arrange the facility for measurement and for handling the people to be measured. Establish waiting room and monitoring areas that should be kept free of contamination. Cover chairs with plastic or other material that can easily be changed.

Information F.78

Example of dose rate indication and dose

To illustrate, in the case of ^{137}Cs, level A, corresponding to a committed effective dose (E_{50}) of 0.5 mSv, would be 4 x 10^4 Bq. Several days after intake, this would give an indication of about 0.05 µGy/h on a survey meter placed 1-2 cm from the body. Under typical conditions, this is roughly equivalent to a 50 % increase compared to the background. Level B, corresponding to an E_{50} of 50 mSv, would be 5 x 10^6 Bq, resulting in a dose rate under equivalent conditions of 5 µGy/h. The arbitrarily chosen decision level in this example, A' = 0.5 mSv, may be unnecessarily restrictive. Such a conservative approach allows for the large uncertainties which exist in the actual correspondences between A' and the estimated value of A (and between B' and B). These relationships would depend not only on factors relating to the measurement, but also on aspects of the individual's metabolism, the circumstances of the intake, and where a mixture of radionuclides was present, on its composition. Moreover, there may be situations in which a given level of internal contamination, insignificant in itself, implies the possibility of significant external irradiation. In practice, the initial choices of decision level A' and B', or the action levels A and B derived from them, may need to be reviewed according to the measurement range of available equipment and the capacity of the more rigorous monitoring arrangements in relation to the demands made on them (IAEA TECDOC 746, 1994).

Information F.79a

Figure F13. "Lap geometry" for whole body measurement with portable gamma spectrometer. This photograph illustrates the method, but when responding to an incident, additional measures would need to be employed, i.e. the detector would be wrapped in plastic film, and the subject would wear disposable gloves. Photo: STUK.

3. Prepare the monitoring equipment. Preferably use NaI or CsI detector. Ensure staff are familiar with the instruments.
4. Switch on the monitor.
5. Set a suitable time for measurement (100 seconds or the standard for the monitor used).
6. Fill in the name of the person and other data indicated in the registry form [Annex 3].
7. Cover the detector with a new plastic bag between each measurement.
8. Start the measurement, record the result and fill in the registry form.
9. Do a background measurement on a non-contaminated person, if possible. Record all details in the measurement protocol.
10. Always check that the form is completed correctly.
11. Inform the person monitored about the result and give her/him the information leaflet "Information for people monitored and/or decontaminated" [Annex 3].
12. Advise the monitored person on suitable follow up actions.

F.80 Thyroid monitoring with hand-held instruments

(PEOPLE MONITORING TEAM)

1. Choose a suitable area for the monitoring with as low a level of background radiation as possible. If this is not possible outdoors, try a building with high shielding factor, a basement or cellar. The facility should be large enough to make it possible to arrange separate waiting and monitoring rooms.
2. Arrange facility for measurement and for handling the people to be measured. Establish waiting room and monitoring area that should be kept free of contamination. Cover chairs with plastic or other material that can easily be changed.
3. Prepare the monitoring equipment. Preferably use NaI or CsI detector. Provide instrument manuals.
4. Switch on the monitor.
5. Set measuring time (100 seconds or the standard for the instrument used).

Information F.79b

Monitoring with hand-held instruments

The minimum detectable amount (MDA) in this type of measurement is about 1–2 kBq for ^{137}Cs (± 50 %) (Zvonova et al, 1995). The uncertainty depends partly on the position of the person and partly on the background to some degree shielded by the body of the person. Since the measurements often are performed in environments with enhanced background the actual background in the person measurement might be difficult to estimate. Comparisons with regular whole body counting measurements have shown satisfactory agreement and the method is useful when remembering the corrections that have to be made and the limitations involved.

Information F.80

Figure F14a. Measurement of ^{131}I in the thyroid.

Figure F14b. Background measurement to be used for the thyroid measurement of a person. This is important for later dose assessment.

Photos: STUK.

These photographs illustrate the method, but when responding to an incident, additional measures would need to be employed, i.e. the detector would be wrapped in plastic film, and the subject would wear disposable gloves.

6. Do an environmental background measurement.
7. Do a reference measurement on a non-contaminated person, if possible.
8. Register the name of the person to be monitored and other information indicated in the registry form [Annex 3].
9. Shield the detector with a plastic bag which should be replaced after each measurement.
10. Keep the detector close to the persons neck when performing the thyroid measurement [Figure F14a, Information F.80].
11. Perform a background measurement, asking the person to keep the detector resting on the thigh as shown in Figure F14b in Information F.80.
12. Record the results and fill in the registry form.
13. Check that the form is completed correctly.
14. Inform the person monitored about the result.
15. Advise the person on suitable follow up actions.

3.4.2 In vitro monitoring

(CONTAMINATION INCIDENT)

F.81 Samples

(TIC, PEOPLE MONITORING TEAM)

Samples that can be used for bioassay are: urine, faeces, nose blow or blood, and in special cases, teeth, hair, nails or saliva. Only nose blow/nasal swabs can be taken at the scene of the incident. For other samples, additional expertise is needed. For sampling, contact a health care centre, hospital or other organisation routinely taking and handling excreta and blood samples. For analysis of the samples, special laboratories are required. The sampling procedures are described in Annex 11.

F.82 Nasal swabs and nose blow samples

(PEOPLE MONITORING TEAM)

For survey of persons at or close to the scene of an incident nasal swabs can be taken outside the Red Zone or for example at the Radiation Monitoring Unit if it is already established [Information

Information Section 3.4.2

Bioassay

Indirect bioassay is the determination of the type, quantity, location and/or retention of radionuclides in the body by *in vitro* analysis of material excreted or removed from the body. The primary use of bioassay procedures is to determine whether an individual has been exposed to radioactive material in a manner that resulted in internal deposition and, if so, to quantify the magnitude of that deposition and its dosimetric consequences (NCRP Report 87, 1987).

For a particular sample, the method of analysis depends primarily on the emissions available for detection. If only particulate emissions are available (α or β particles), or the yield or energies of any photon emissions are very low, these radionuclides may first need to be separated from the sample matrix to achieve good and reproducible detection. In the case of urine (or other liquid) samples, however, direct dispersion of a small volume of the sample into a liquid scintillant may be sufficient.

Radionuclides emitting penetrating photons can, in general, be quantified in bulk samples. Although these radionuclides may also be detectable in the body, by direct counting, detection in excreta may be more practical or the only possibility if direct monitoring is not available.

E.45]. The activity detected in the swabs can be used to estimate intake by inhalation. Lung contamination is estimated to be about 5 % of total radioactivity measured from swabs of both nasal cavities, but the estimation is rather uncertain. The swab collection should be done before nasal decontamination, sneezing etc. If activity is found only in one nostril the contamination is probably non-respiratory. Swabs must be dry when surveying for alpha emitters. During a large contamination event, there will not be time to do analysis by nasal swabs, but instead nose blow could be used for screening purposes [Annex 11].

F.83 Urine samples

(PEOPLE MONITORING TEAM)

The method for collection of urine samples depends on the aim of measurement, e.g. whether it is for confirmation of internal contamination (spot sample) or for dose assessment purposes (24 hour sample) [Annex 11].

Contact a suitable organisation, health care centre or other organisation routinely taking and handling excreta samples, and arrange the procedure for sampling. Contact a laboratory, or if it is a mass casualty event, more than one laboratory able to analyse the samples for the radionuclides of concern may be required. A spot sample is enough for confirmation of internal contamination, but for dose assessment purposes 24 hour samples should be used [Instruction J.24].

F.84 Faecal samples

(PEOPLE MONITORING TEAM)

Contact a suitable organisation, health care centre or other organisation routinely taking and handling excreta samples, and arrange the procedure for sampling. Contact a laboratory, or if it is a mass contamination event, more than one laboratory that is able to analyse the samples for the radionuclides of concern may be required. The usual faecal sample is a single voiding, but for dose assessment purposes, faeces should be collected for a period of 2-3 or even 5 days. Consult a dose assessment specialist for advice [Instruction J.24].

Information F.85

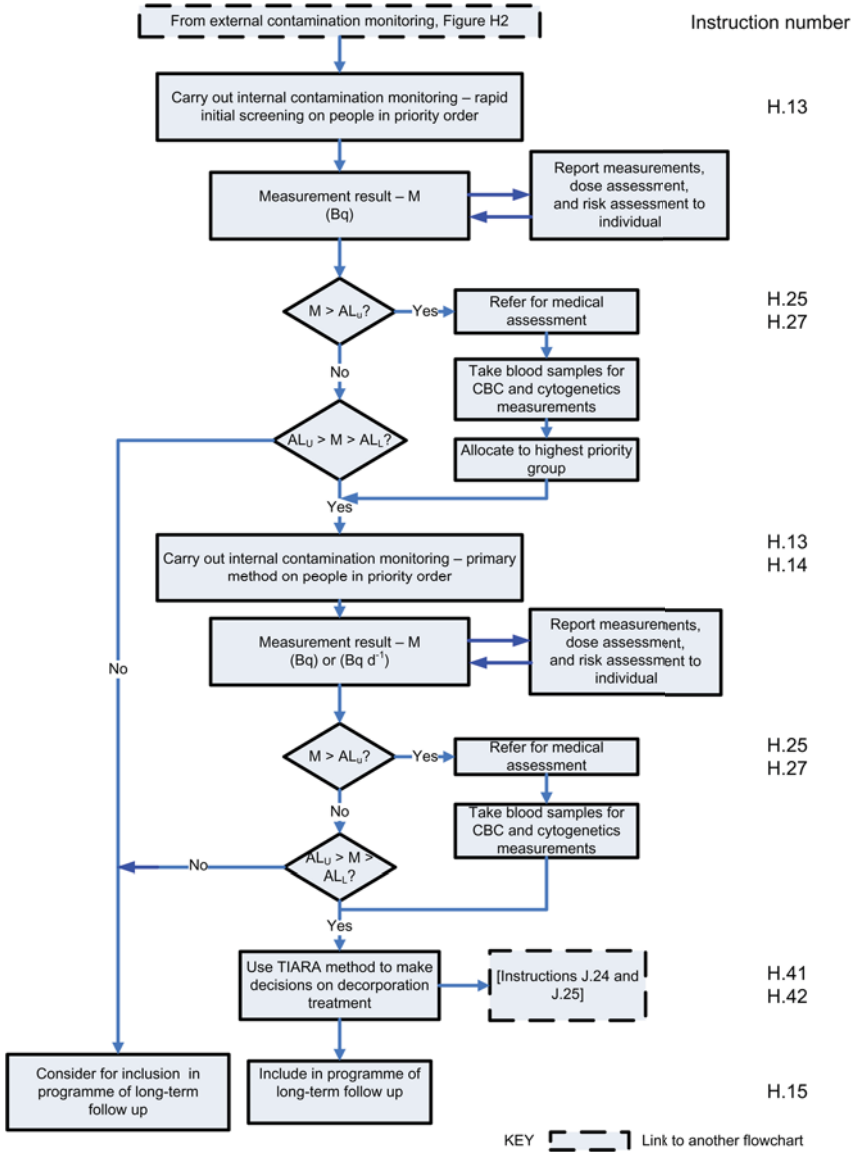


Figure F15. Recommended procedures for internal contamination monitoring (also presented in Figure H3 [Section H.4.3.3] with explanatory text).

F.85 **Comparing measured levels (M) to Action Levels (AL)**
(PEOPLE MONITORING, RADIOLOGICAL TRIAGE, MEDICAL TEAMS)
Results of internal contamination monitoring should be interpreted using the procedures described in Figure F15. Measured levels of internal contamination should be compared with the Action Levels given in Annex 10. The procedures are described and explained in more detail in Section H.4.1.

F.86 **Actions based on M vs. AL**
(PEOPLE MONITORING, RADIOLOGICAL TRIAGE, MEDICAL TEAMS)
On the basis of the comparison of measured levels with Action Levels [Annex 10], the actions specified in Table F3 [Information F.74] should be carried out.

4 Advice on dealing with psychological issues

F.87 **Staff roles**
(MEDICAL TEAM)
One or more members of the medical team should be assigned to dealing with psychological effects on people affected by the incident. Ideally, they should have received training for this role. Other staff working in the field should not be diverted from their main responsibilities in an attempt to deal with the psychological impact of the event on individuals. Instead, people affected in this way should be referred to the member(s) of the medical team assigned to this task.

F.88 **Initial psychological effects**
(ALL TEAMS)
Staff whose duties bring them into contact with members of the public should be aware that any event dealt with by this Handbook may result in adverse psychological effects in the people they are dealing with. These staff should make themselves familiar with the contents of Section K.8. They should be alert to the possible initial reactions of people involved in the incident. These could include

Information F.88a

Section K.8 summarises the main issues relating to the management of psychological impact in radiation emergencies, but does not provide prescriptive guidance. Section F.4 presents brief guidelines for teams working in the field on dealing with psychological impact.

Information F.88b

A radiation emergency resulting from a malevolent act is a highly stressful event. It may act as a powerful and persistent stressor even after the emergency has been controlled. Psychological reactions following man-made disasters, such as malevolent acts, are more intense and more prolonged than psychological reactions following natural disasters. They may include multiple symptoms like fear, grief, anxiety, anger, depression and distrust. Psychosomatic symptoms are frequent and differential diagnosis and treatment of physical and psychological conditions will be essential during the early stage of the event, including the triage of people.

Ionising radiation cannot be perceived by the senses and most people are not familiar with the magnitude of its effects, which could result in community-wide feelings of helplessness and vulnerability. Disasters with a high degree of uncertainty regarding the potential of future health effects are more psychologically traumatic than situations with more visible, immediate, and predictable outcomes. Moreover, the fact that the control of the situation is normally in the hands of the government (i.e. out of citizens' hands) increases the degree of feelings of vulnerability in the population. Emotional reactions may affect both casualties and responders, and these reactions may be so intense and severe that they could even affect decision-making and operations.

disbelief, bewilderment, stupefaction, fatigue, impaired concentration, emotional numbing and social withdrawal.

F.89 **Role of the medical team**

(MEDICAL TEAM)

Assigned staff from the medical team should attempt to calm and reassure individuals who are experiencing adverse psychological effects. In the longer term, affected people should be advised to contact their family doctor, who may decide to refer them for specialist help.

F.90 **Dealing with members of the public**

Staff whose duties bring them into contact with members of the public should have good interpersonal skills. They should communicate with people calmly and openly, but should focus on their primary duties and not engage in conversation unnecessarily. They should take care to use language that is understandable by the layman, and avoid technical jargon. Communication should be two-way; staff should spend time listening as well as speaking. They should avoid transmitting any concerns or anxieties they may have themselves. If asked, they should communicate objective information about the incident, or about measurements they are performing on the individual, whenever possible. Information provided should be accurate; providing inconsistent information will act to reduce confidence. Information relevant to the health of a particular individual should not be withheld from that person; such actions will only act to reduce their confidence in the organisations responding to the incident. On the other hand, if staff do not have the information needed to respond to a particular query, they should say so. Taken together, these measures should have the effect of reducing the general level of stress and anxiety.

CHAPTER G

Decontamination of people in the field

Introduction

Decontamination of people described in this section refers to the removal of radioactive contamination and not removal of chemical or biological material.

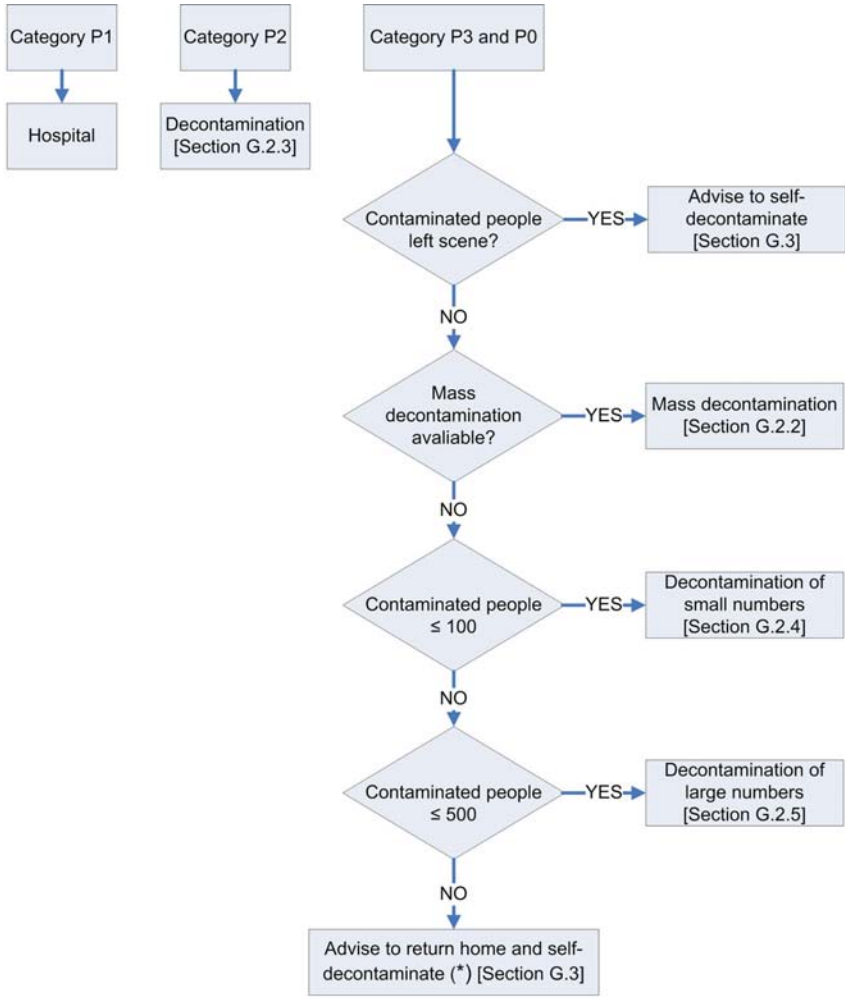
People who have only been externally irradiated do not require decontamination.

People involved in an incident where radioactive material is present in the environment will be prioritised for decontamination using the procedures detailed in the triage section [Section F.2].

Contamination with radioactive materials is not immediately life threatening. Decontamination should be carried out as soon as possible, but does generally not require the same immediacy as chemical or biological contamination, except in extreme circumstances where the contamination is sufficient to cause deterministic effects [Section H.4].

Decontamination of injured people will take place either in hospital or adjacent to the incident, depending on the severity of injuries; details are given in the section on triage and monitoring [Chapter F].

Information G.1



(*) Only if in a low risk group. Otherwise advise to wait until facilities are available

Figure G1. Flowchart for decontamination of people.

1 Preparations for decontamination of people

(CONTAMINATION INCIDENTS)

G.1 Strategy

(TACTICAL INCIDENT COMMAND [TIC], DECONTAMINATION TEAM)

1. The decontamination team should work according to the strategy summarised in Figure G1. The details of the strategy depend on:
   - Severity of injury to people requiring decontamination;
   - Number of people requiring decontamination; and
   - Availability of decontamination facilities.

The instructions in this section explain how to carry out the strategy.

2. If necessary, inform Decontamination Team members that concerns about their own radiation exposure resulting from cross contamination must not prevent people decontamination procedures from taking place.
3. If the wait for decontamination exceeds 2 hours, or is likely to exceed 2 hours, then additional decontamination facilities should be introduced, or the method of decontamination revised.
4. If the number of people requiring decontamination, or the lack of decontamination facilities, would mean decontamination would be delayed by more than 2 hours, uninjured people with a low priority for decontamination [Section F.2] can be encouraged to go home and self-decontaminate [Section G.3]. If possible transport should be provided to reduce the spread of contamination.

G.2 Location of decontamintation facilities

(TIC, MEDICAL TEAM, DECONTAMINATION TEAM)

1. If injured people are sent to hospital before being decontaminated, then the receiving medical facility must be

Information Chapter G

Contamination

Decontamination procedures are straightforward; removing clothing and washing the body with soap and water will eliminate most external contamination. Removal of outer clothing, without washing may reduce contamination by 80-90 %.

Cross-contamination (spreading of contamination from person to person) is a secondary concern, especially when the contaminated area or the affected population is large.

Information G.1

The values in the table below can be used to give an upper bound on levels of contamination on surfaces (including survivors).

Table G1. Potential surface contamination from a RDD from a large radioactive source[a].

Radionuclide	Surface contamination (GBq m^{-2})		
	10 kg HE[b] (9-270 m)[c]	100 kg HE (19-550 m)	1000 kg HE (40-1200 m)
^{60}Co	4.8 - 780	1.6 - 230	0.56 - 170
^{137}Cs	33 - 7400	7.4 - 3300	1.5 – 1700
$^{90}Sr/^{90}Y$	11 -1900	3.5 - 520	0.81 - 350

[a] The radioactive sources are of the order of 10^6 GBq. The intention is to provide a realistic upper bound for contamination of surfaces from a maximum credible event.
[b] The quantity of high explosive (HE) designated is not the quantity used in the device, but rather is used to establish the range of probable survivability only.
[c] The range of distances from closest for survivability to safe stand-off.

Adapted from Smith et al, 2005.

informed they will be receiving potentially contaminated casualties.

(TIC, DECONTAMINATION TEAM)

2. Decontamination of casualties who do not require urgent medical attention, and of uninjured people who are evacuated from the Red Zone, should be carried out in the Yellow Zone at the People Processing Area [Section F.2 and Section E.3].
3. Decontamination of casualties who do not require urgent medical attention, and of uninjured people who have self evacuated from the Red Zone to outside the Security Perimeter, should be carried out in a building in, or near, a Reception Centre [Section F.2], located outside the Security Perimeter. This Reception Centre must meet the specification given in Information E.45.

(ENVIRONMENTAL MONITORING TEAM)

4. Decontamination facilities outside the Security Perimeter should be monitored, prior to use, to ensure dose rates are close to natural background levels [Information E.45].

G.3 Requirements before decontamination can take place

(TIC, DECONTAMINATION TEAM)

1. Replacement clothing must be available in sufficient quantities before decontamination can commence, except where doses sufficient to produce deterministic effects are possible; under these circumstances decontamination is urgent. Blankets or similar should be provided if replacement clothing is not immediately available.
2. A one-way system should be established so that people in need of decontamination do not come into contact with those people who have been decontaminated. Areas for decontamination must have separate entrance and exit points.
3. Warm water should be used in showers. Cold water can be used if the air temperature is above 20 ˚C, or medical advice has been given that the risk from hypothermia is negligible.
4. While decontamination is taking place it will be necessary to:
   - Keep families together;
   - Where possible respect cultural and gender differences;
   - Assist people with medical problems; and

- Answer questions relating to radiological protection [Annex 3].

5. Personnel carrying out decontamination procedures must wear appropriate PPE [Section E.1].
6. If possible, clothing should not be removed over the head. However, with the exception of people in triage category P2, there is no need to remove clothing by cutting.

2 Decontamination procedures

2.1 Instructions common to all decontamination procedures

G.4 Common instructions for decontamination

(DECONTAMINATION TEAM)

1. People awaiting decontamination should be advised not to eat, drink or smoke and keep hands away from mouth, until decontamination procedures are complete.
2. While people are waiting for decontamination, they should be given moist wipes with instructions for washing the face and hands. Bags for disposal of used wipes must be provided.
3. Plastic bags for valuables (keys, wallet, prescription medicines etc.) must be provided for all people, before they are decontaminated. These should accompany the person throughout decontamination procedures.

(DECONTAMINATION TEAM, RECORDS TEAM)

4. A registration form for each person must be completed (an example form that can be customised is provided in Annex 3). This should include a reference to the clothing bag, perhaps by using a bar code.

(DECONTAMINATION TEAM)

5. People undergoing decontamination procedures must be issued with information on where to get further information and instructions when released [Annex 3].
6. If possible, a receipt should be issued for contaminated clothing.

(PEOPLE MONITORING TEAM, DECONTAMINATION TEAM)

7. Move potentially contaminated items to a secure store at regular intervals.
8. The effectiveness of people decontamination must be confirmed by monitoring [Section F.3]. The number of people monitored to confirm effectiveness will depend on availability of monitoring resources. Decontamination should not be slowed down due to the lack of resources to monitor decontamination effectiveness.

2.2 Decontamination using specialist mass decontamination facilities

G.5 Procedures

(DECONTAMINATION TEAM)

Procedures may vary depending on the individual specialist mass decontamination facilities available. Procedures to be followed will be similar to those for "Decontamination of small numbers of people" [Section G.2.4]. Assistance for injured people will be required.

2.3 Decontamination procedure for people in trauma triage group P2

G.6 Staffing

(MEDICAL TEAM)

1. As people in this category are injured, this procedure must only be carried out by medically trained personnel.
2. Teams of at least 2 people are required for each patient. Explain what you are going to do, before you start and as you proceed, as this will be an unpleasant, frightening procedure for most people.

G.7 Disrobing procedure

(MEDICAL TEAM)

Remove/cut off clothing, do not pull clothing over the head.

1. If clothing is adhering to the skin, soak with water until clothing can be separated from the underlying tissue to avoid damaging the skin.

Information G.5

Specialist mass decontamination equipment

These are usually temporary buildings or enclosures containing shower facilities; an example is shown in Figure G2. The procedures used for this type of equipment are similar to that described in [Section G.2.4]. Typically the units can be erected in minutes and are capable of decontaminating up to 100 people per hour. The units consist of three sections, an area to disrobe, a shower area using warm water, and a re-robe area. In some units, non-ambulant casualties can be decontaminated on stretchers, but at a much lower rate (10 casualties per hour).

Ideally, the correct percentages of detergent should be mixed with the water before these facilities are used, but plain water can also be used.

Figure G2. Example of a specialist mass decontamination unit. Photo: HPA.

2. Fold clothing outside to middle and place in a large labelled plastic bag.
3. Spectacles should be washed, dried and returned to the patient, hearing aids should be wiped thoroughly with saline-moistened gauze and returned to the patient.

G.8 Washing procedure

(MEDICAL TEAM)

1. Step 1: Gently wash affected areas with soap and water (5 ml per litre), and use saline for open wounds and the surface of the eyes.
2. Step 2: Wipe affected areas gently but thoroughly with sponge or soft brush (DO NOT abrade the skin).
3. Step 3: Rinse affected areas.
4. Decontaminate the face first and sites needed for intravenous access.
5. Next, irrigate any open wounds with saline and cover with a dressing.
6. Then, working from hair/head to toes, pay special attention to skin folds and creases, nails, ears and legs, and other areas which were not covered by clothing. If possible, roll patient onto their side to reach their back.
7. Eyes: if contact lenses are present, remove if possible without harm; use topical anaesthetic if needed; flush eyes copiously with saline.
8. Dry and clothe patient.

2.4 Decontamination of small numbers of people

G.9 Strategy

(DECONTAMINATION TEAM)

1. If the number of people requiring decontamination is less than around 100, the following procedure should be used, as this is likely to be more effective than procedures which do not use showering.
2. The decontamination facility should be established in an area with showering facilities, ideally with separate areas for males and females.

Figure G3. Mobile decontamination unit. Photo: Norwegian Civil Defence.

G.10 **Procedure**

(DECONTAMINATION TEAM)

Provide each person with instructions to:

1. Remove all clothing and place it in a plastic bag, which should then be tagged and sealed.
2. Gently blow nose and wash out eyes and ears.
3. Shower thoroughly with warm (not scalding hot) water and soap, allowing the water to run away from the face. Wash hair, but do not use hair conditioner as this would fix the contamination to the hair.
4. Use the mechanical action of flowing water and/or a cloth, sponge or soft brush.
5. Avoid causing mechanical, chemical or thermal damage to the skin.
6. Change into clean clothing.

Wash out shower between people.

2.5 Decontamination of larger numbers of people

G.11 **Strategy**

(DECONTAMINATION TEAM)

These decontamination procedures should be used when the number of people requiring decontamination exceeds the capabilities of the procedure for decontamination of small numbers of people [Section G.2.4].

G.12 **Procedure**

(DECONTAMINATION TEAM)

Provide each person with instructions to:

1. Remove all clothing and place it in a plastic bag, which should then be tagged and sealed.
2. Gently blow nose.
3. Wash face and hands with water or a damp cloth.
4. Change into clean clothing.
5. Follow procedure for decontamination at home when released [Section G.3)].

Figure G4. Demonstration of decontamination of people who need assistance. Photos: HPA.

3 Self-decontamination at home

G.13 **Strategy**

(CONTAMINATION INCIDENTS) (TIC)

1. For incidents involving large numbers of people, the uninjured and people in category P3 can be encouraged to go home and self-decontaminate providing they are assigned a low priority in the triage process, and may be monitored at a later date. It is also likely that some people will self-evacuate and return to their homes, and these people must also be instructed to follow this procedure.
2. Guidance must be given to this population through the media (television, newspapers, teletext, radio, or telephone/internet based healthcare service e.g. NHS Direct in UK) on what to do and how to perform their own decontamination. This guidance should include the following:
   - Explain that, like dirt, most contamination washes off with soap and water. They should be advised to act as if they were going home in clothes covered with mud and did not want to spread it into their homes; and
   - Provide instructions for them to:
     - Undress at the external doorway or in their garage
     - Remove clothing and place it in a plastic bag which should then be sealed and placed in a store, away from the living areas
     - Gently blow nose and wash out eyes and ears
     - Shower or bath thoroughly with warm (not scalding hot) water and soap, allowing the water to run away from the face. Wash hair but do not use hair conditioner as this will fix the contamination to the hair
     - Use the mechanical action of flowing water and/or a cloth, sponge or soft brush
     - Avoid causing mechanical, chemical or thermal damage to the skin (e.g. scrubbing to hard)
     - Change into clean clothing
     - Wash out bath or shower
     - Wash car if they drove home from the area of contamination
     - Tune in to television or radio for further instructions.

3. The bagged clothing is not likely to be heavily contaminated, but it may form a source of irradiation for the public. There may be a need for later contamination monitoring of the clothes. A course of action will need to be decided after the radiological assessment of the incident. It may be possible to return clothing to use after laundering, but it may also be necessary to treat it as radioactive waste.

4 Contamination control

G.14 (DECONTAMINATION TEAM, ENVIRONMENTAL MONITORING TEAM)
Personnel carrying out decontamination procedures must be monitored for contamination every hour. If contamination is found on clothing it must be changed. If contamination is found on the skin, then staff must go through the decontamination procedure. Decontamination facilities must be monitored every hour for contamination [Section F.3.3].

5 Waste considerations

G.15 (TIC, DECONTAMINATION TEAM)
1. Equipment used for decontamination, in particular sponges, towels, brushes etc. should be stored for eventual safe disposal.
2. Do not attempt to contain contaminated water. Alert relevant authority that contaminated water has been discharged.

Figure G5. Remember to monitor personnel for contamination. Photo: Norwegian Civil Defence.

CHAPTER H

Monitoring for dose assessment purposes

1 Objectives of individual monitoring

The term "monitoring", sometimes also known as "radiological monitoring", describes the measurement of radiation dose or contamination for reasons related to the assessment or control of exposure to radiation or radioactive material, and the interpretation of the results.

Individual monitoring is monitoring using measurements of quantities of radioactive material in or on the body of the individual, or measurements made by equipment worn by individual workers. It includes the assessment of radiation doses to the individual from the results of such measurements. In the present context, the objectives of individual monitoring are closely associated with the objectives of triage described in Section F.1. The main objectives are:

1. To quantify absorbed doses to organs and tissues for people exposed to radiation or radioactive material at a level high enough to potentially give rise to deterministic health effects.
2. To provide the dosimetric information that would allow urgent decisions to be made to remove individuals from a source of external exposure, or to remove or reduce contamination on or in the body.
3. To quantify committed effective doses for people with lower levels of internal contamination that could result in an elevated risk of stochastic health effects.
4. To provide dosimetric information that could be used when making decisions on medical treatment for the groups of people identified in objectives 1 and 3.
5. To quantify committed effective doses for people whose exposures are very unlikely to have an effect on health, or who were not exposed at all.

Secondary objectives include the prevention of further exposures, the provision of information to individuals on their levels of exposure, and the provision of information to the appropriate authorities on the radiological consequences of the incident.

Information Section H.1

Definitions of radiological monitoring

These definitions are adapted for the specific case of monitoring in the event of an incident involving the malevolent use of radiation or radioactive material from the IAEA's safety glossary (IAEA STI/PUB/1290, 2007).

2 Specifying a monitoring strategy

Introduction

What is a monitoring strategy?

In the initial stages of the response, there will be little time to carry out detailed planning of the response, and minimal information on which to base such plans. Anticipating this, Chapters E, F and G describe actions that can be implemented automatically without the need to develop detailed plans that are specific to the incident.

After these initial actions are under way, perhaps after 24-48 hours have passed, there will be time to develop a monitoring strategy. This is a general plan for the radiological measurements and assessments needed to provide the necessary information on actual or potential effects on health. The plan will take into account the specific characteristics of the incident, and the information received as a result of the initial stages of triage and monitoring.

Topics addressed by a monitoring strategy are:

- Identification and characterisation of radionuclide(s);
- The people to be monitored;
- Where individual monitoring should be carried out;
- The individual monitoring methods to be employed;
- When individual monitoring should be carried out;
- Action levels to trigger the various actions to be performed after individual monitoring;
- Long-term follow up monitoring; and
- Recording and reporting of monitoring results.

This section does not specify the monitoring strategy itself, because this will depend on information that will only become available as the incident progresses. Rather, it details the steps that need to be carried out to develop the monitoring strategy. The strategy may be implemented by making use of the material in Section F.3, Section H.3, Section H.5, Section H.6, Annexes 6-10 and Annex 13. The use of monitoring information to make radiological triage decisions, including on the need for further monitoring, is described in Section H.4.

A monitoring strategy is part of the public health response. It does not address the monitoring necessary for individuals who may be at risk of developing deterministic health effects.

Actions should be carried out by the TIC in collaboration with the relevant team leaders.

H.1 **Incident status**
(TIC)
If any of the stages described in Information H.1 have not yet commenced, refer to Chapters E, F, G.

2.1 Identification of radionuclide(s)

H.2 **Dispersed radionuclides**
(CONTAMINATION INCIDENTS) (TIC)
All contaminant radionuclides dispersed into the environment as a result of the incident must be identified.

H.3 **Irradiation source**
(EXTERNAL IRRADIATION INCIDENTS) (TIC)
The radionuclide(s) present within an irradiation source must be identified. It would probably be a high yield gamma-ray emitter and therefore easily identifiable using a portable radionuclide detector.

2.2 Characterisation of source

H.4 **Temporal variation**
(TIC)
Any temporal variation of gamma dose rates and contamination levels (of alpha, beta and gamma-emitting radionuclides) within the Red and Yellow Zones should be quantified. This will require a programme of regular area surveys to be carried out, until the situation has been stabilised. Initial surveys should be carried out frequently (e.g. hourly) until the magnitude of any temporal variation is established.

H.5 **Air sampling**
(CONTAMINATION INCIDENTS) (TIC)
A programme of air sampling, using high volume air samplers, in areas where people are located should also be established. Samples should be collected and measured at regular intervals.

Information H.1

Incident response status
It is assumed that the following have been established or are well advanced at the point at which development of the monitoring strategy is initiated:

1. It has been established whether or not the incident has resulted in:
   - trauma injuries;
   - distribution of radioactive contamination; and/or
   - exposures that could result in deterministic health effects.
2. Initial zone boundaries have been established.
3. Gamma dose rates and contamination levels (of alpha, beta and gamma emitting radionuclides) within the Red and Yellow Zones have been mapped.
4. Trauma triage is complete or well advanced.
5. Radiological triage based on information on location is in progress.
6. Radiological triage based on clinical signs and symptoms is in progress.
7. Initial monitoring of people for external contamination is in progress, but internal contamination monitoring has not yet commenced.
8. Decontamination of some individuals is under way.

Some elements of the response may be more advanced than described here. This should not affect the development of the monitoring strategy.

Information H.2

Radionuclide identification must be performed to enable internal doses to be assessed and to inform decisions on decorporation. Gamma-emitting radionuclides (e.g. ^{137}Cs, ^{60}Co) may be easily identified using a portable radionuclide detector. Use of such detectors may also assist in identifying alpha-emitting and pure beta-emitting contaminants (by detection of low yield photon emissions, and in the latter case Bremsstrahlung radiation). Samples should be taken at the scene for urgent gamma and alpha spectrometric analysis at specialist laboratories [Section F.3 and Section H.4.3]. The identity of alpha-emitting and pure beta-emitting contaminants must be confirmed on the basis of this sample analysis.

Information H.4 and H.5

Temporal variation will arise if the contaminant material is moving. This may arise because material in the form of a dust or aerosol is being resuspended in air. If this is happening, there is a risk of further exposures by inhalation.

H.6 **Assessment of potential exposures**

(TIC)

Predictive assessments should be made of potential exposures to individuals (particular emergency services workers) present within the Red Zone on the basis of this air sampling. It should be confirmed that the relevant dose constraints are not (and will not be) exceeded [Section E.1].

2.3 Selection of individuals for monitoring

H.7 **Individual monitoring**

(TIC)

Individual monitoring should be carried out on people selected and prioritised according to Instructions F.23, F.26 and F.27. The various stages of the triage process should be reviewed at regular intervals to confirm that individuals have been correctly selected, and to select new individuals as appropriate.

H.8 **Representative monitoring**

(TIC)

If the numbers of people requiring monitoring exceed the available capacity, then priority must be given to people who could potentially have levels of contamination that could have an effect on physical health. For other groups of people, representative individuals should be selected. The results for these individuals may be taken to be typical of other people in the group, providing that monitoring results support this assumption.

H.9 **Reassurance monitoring**

(TIC)

After all those people selected using the procedures described in Section F.2 have been monitored, individuals who were not immediately selected may be considered for monitoring. The main purpose is expected to be the provision of reassurance to individuals and to the public at large that significant sources and pathways of contamination have not been overlooked.

Information H.7

Selection of individuals for monitoring should already be in progress [Section F.2]. However, the various stages of triage should be regularly reviewed because it is a dynamic process. Further information will become available that will generally be more detailed and more accurate. It should be expected that new individuals will be selected for monitoring.

Information H.9

Monitoring of people who were not immediately selected for monitoring

After individual monitoring has been completed for those groups of people who were positively selected by the triage process after a contamination incident, there will almost certainly be demands to extend monitoring to other individuals or groups for reassurance or public information purposes. It will in any case be necessary to carry out further individual monitoring on limited groups of people to determine whether predictions or expectations regarding spread of contamination are correct; (for a contamination incident, this would involve extending monitoring to people who were not within the Red Zone during the incident). Analysis of the results for people already monitored will give an indication of the extent to which the target population for monitoring may need to be extended.

A large scale programme of public monitoring could well overwhelm available resources, so any commitments made should be carefully considered in advance. Where the aim is reassurance, arrangements for any monitoring programme should be fully integrated with arrangements for dissemination of information to the public. To avoid over commitment of resources, representative individuals from defined groups could be monitored. Release of information on such monitoring may well act to reassure other members of the group. Where contamination could be widespread, individuals to be monitored could be selected on the basis of their place of residence using a geographic grid. Professional people who work with the community (health visitors, nurses, teachers, police, local council members, etc.) may well be willing to cooperate in such a monitoring programme.

2.4 Locations for individual monitoring

H.10 **Re-location**
(CONTAMINATION INCIDENTS) (TIC)
Potential or current locations for monitoring should be reviewed to ensure they meet (and will continue to meet) the criteria specified in Information E.45.

H.11 **Consideration for location**
(CONTAMINATION INCIDENTS) (TIC)
Initial monitoring locations are likely to have been sited in the Yellow Zone because of its proximity to people being evacuated from the Red Zone. After monitoring has been completed for this group of people, locations outside of the Yellow Zone should be employed that meet the criteria specified in Information E.45.

2.5 Individual monitoring methods

H.12 **External contamination measurements**
(CONTAMINATION INCIDENTS) (TIC)
The results of external contamination measurements should be interpreted using the Action Levels given in Annex 10. Depending on the results of these measurements, the actions described in Table H4 [Information H.35] should be carried out.

H.13 **Rapid screening**
(CONTAMINATION INCIDENTS) (TIC)
Wherever possible, rapid measurements of internal contamination should be carried out using the rapid screening method identified in Table H1 [Information H.13], for all people selected for this type of monitoring by the triage process [Section F.2]. The results should be interpreted using the Action Levels given in Annex 10. Depending on the results of these measurements, the actions described in Table H4 [Information H.35] should be carried out.

Measurements made using the rapid screening method should be carried out within 24 hours.

Information H.13 and H.14

Individual monitoring methods

The primary monitoring method should be that which is expected to provide the most reliable assessment of internal dose. The measurement is likely to be carried out in a laboratory. For most radionuclides, more rapid measurements can be carried out in the field, although these will, in general, be less accurate. Such measurements are of most use for rapid triage purposes, and are referred to here as *rapid screening methods*. Descriptions of these methods are given in Section H.3 and Annex 8. An explanation of the principles underlying the choice of monitoring methods is given in Annex 6.

Table H1. Individual monitoring methods.

Radionuclide (absorption type)[1]		Radiation type emitted	Rapid screening method	Primary monitoring method
Manganese-54 (F)	^{54}Mn	γ (EC)	Whole body (rapid)	Whole body[4]
Cobalt-60	^{60}Co	β, γ	Whole body (rapid)	Lung[5]
Strontium-90	^{90}Sr	β	Nose blow/nasal swab[6]	Urine
Selenium-75	^{75}Se	γ (EC)	Whole body (rapid)	Whole body
Silver-110m	^{110}Ag	β, γ	Whole body (rapid)	Whole body
Cadmium-109	^{109}Cd	γ (EC)	Whole body (rapid) Nose blow/nasal swab	Whole body, urine
Iodine-131	^{131}I	β, γ	Thyroid (rapid)	Thyroid
Barium-133	^{133}Ba	γ (EC)	Whole body (rapid)	Whole body
Caesium-137	^{137}Cs	β, γ	Whole body (rapid)	Whole body
Europium-152	^{152}Eu	β, γ	Whole body (rapid)	Whole body
Europium-154	^{154}Eu	β, γ	Whole body (rapid)	Whole body
Iridium-192 (F)	^{192}Ir	β, γ	Whole body (rapid)	Whole body[4]
Polonium-210	^{210}Po	α	None	Urine
Radium-226	^{226}Ra	α	Nose blow/nasal swab	Lung[5], Urine
Plutonium-238	^{238}Pu	α	Nose blow/nasal swab	Urine, Faeces[2] (Lung[3,5])
Americium-241	^{241}Am	α, γ	Nose blow/nasal swab	Lung[5]
Californium-252	^{252}Cf	α	Nose blow/nasal swab	Urine, Faeces[2] (Lung[3,5])

α – alpha emitter β – beta emitter γ – gamma emitter EC – electron capture

1. The Absorption Type (F, M or S) to which a chemical compound is assigned [Table H8] reflects the rate at which it is absorbed from the respiratory tract to body fluids.
2. Faecal monitoring is unlikely to be suitable for large numbers of people.
3. Lung monitoring has very low sensitivity for these radionuclides. Nevertheless, the sensitivity is adequate for the detection of contamination levels that could result in deterministic effects.
4. Different primary monitoring methods are recommended for compounds of manganese and iridium other than those allocated to Absorption Type F [Annex 10].
5. Intake by inhalation only. For ingestion, see Table A10.1, Annex 10.
6. Nose blow/nasal swab monitoring is not suitable for soluble compounds of ^{90}Sr [Table H8].

H.14 **Primary monitoring method**

(CONTAMINATION INCIDENTS) (TIC)

More accurate measurements of internal contamination should then be carried out using the primary monitoring method identified in Information H.13, for all people selected by the triage process for this type of monitoring [Section F.2]. The results should be interpreted using the Action Levels given in Annex 10. Depending on the results of these measurements, the actions described in Table H4 [Information H.35] should be carried out.

In general, measurements made using the primary monitoring method may be delayed for a number of days, if lack of monitoring resources makes this necessary.

H.15 **Long-term follow up**

(CONTAMINATION INCIDENTS) (TIC)

People selected by the triage process for this type of monitoring may be included in any programme of long-term follow up measurements [Section K.9].

H.16 **Blood cell counts**

(TIC)

For people selected by the triage process for CBC [Section F. 2.2.2], a programme of blood sampling should be specified.

H.17 **Chromosome aberration analysis**

(TIC)

For people selected by the triage process for this type of monitoring [Section F.2.2.2], but who are not being admitted to hospital, a programme of blood sampling for cytogenetic analysis should be specified [Section J.10]. In collaboration with medical personnel, prioritisation of samples to be sent/analysed should be made. First priority: samples from people without symptoms for days or more but with anticipated exposure. If this group is large, there will be a need to prioritise again. Groups of the population likely to be vulnerable to radiation should be prioritised (children, pregnant women etc.). If the group without symptoms is large, representatives from groups of people with similar anticipated doses may be selected first. Samples from people allocated to lower

Information H.17

Biological dosimetry requirements and strategy

Biological dosimetry is not the first diagnostic method to be used for radiation exposed subjects. First dose assessments should be based on symptoms. Except for people with very serious *prodromal symptoms* who will be taken immediately to the hospital, the best dose estimations are achieved if the blood samples are taken 24 hours after exposure.

Biodosimetry by cytogenetics is more efficacious for external and penetrating radiation.

In the case of low penetrating radiations such as beta radiation and low energy x-rays, it is not very useful. For exposures from internal contamination, biological dosemeters could be useful, but usually they do not work well. Biological dosemeters can be used in such cases to detect elevated levels of internal contamination but not necessarily for dose reconstruction purposes.

For exposures resulting from internal contamination, bioassay measurements can be used to assess internal doses with much greater sensitivity than can be obtained with cytogenetic dosimetry. In the case of direct measurements (i.e. on whole body or organs), results can be obtained almost immediately, while indirect measurements (i.e. on excreta) can provide initial results within 48-72 hours, depending on the radionuclide.

The detection limit for the most sensitive biological dosimetry method – dicentric assay – is 0.1 Gy.

In the case of large scale emergencies, with great numbers of casualties, the biological dosimetry triage approach is a strategy for increasing throughput. In such situations most laboratories will be able to cope with up to 100 patients, but the detection limit will be 1 Gy. An additional strategy to speed-up biodosimetry is the development of interactive networks between experienced laboratories, along with the assistance of clinical laboratories in hospitals doing cytogenetics (e.g. karyotyping, micronucleus assay) to provide satellite scoring support. Utilising all the formal and informal networks (world-wide) it could be possible to deal with several hundreds of patients in the short term (1-2 weeks). Descriptions of cytogenetic methods are given in Section J.10 and additional information in Annex 9.

priorities may be sent for biological dosimetry analysis one or more weeks after accident. Realistic estimates should be made of the time required to provide the results of measurements and associated dose assessments.

H.18 **Dosimetry on personal belongings (EPR and OSL)**
(TIC)
Measurement of doses on the basis of measurements of objects present in people's pockets, clothes or other personal belongings may be considered (EPR and OSL are described in Information H.18 and Annex 9).

Analysis will need to be performed at specialist laboratories [Section J.10 and Annex 1].

H.19 **Time to report results**
(PEOPLE MONITORING TEAM, TIC)
Realistic estimates should be made of the time required to provide the results of measurements and associated dose assessments, and this information should be provided to the TIC and to other teams awaiting monitoring results.

H.20 **Action Levels**
(CONTAMINATION INCIDENTS) (TIC)
Action Levels for making decisions on decontamination, referral for medical assessment, additional monitoring, provision of information to individuals, and inclusion in any programme of long-term follow up monitoring should be set as described in Section H.4.

Information H.18

Dosimetry on personal belongings
In some cases externally irradiated individuals can be monitored indirectly by measuring personal objects carried during exposure (e.g. tablets, other objects in the pockets). Two approaches are possible;

- EPR spectroscopy that can be applied at higher doses and for small numbers of individuals (usually requested at later stages of monitoring); and
- Optical stimulated luminescence (OSL) and thermoluminescence (TL) techniques may be performed on a wide variety of natural and manufactured materials (e.g. objects usually present in people's pockets such as chips in credit cards and mobile phones (Inrig et al, 2008; Barkyoumb and Mathur, 2008)). The method is suitable for detection of very low doses from the range 10-100 mGy up to 10 Gy and has great potential for population triage, since measurements can be made rapidly with a semi-automatic reader, more than several tens per day.

These methods are still subject of ongoing research.

3 Monitoring techniques

Introduction

This section presents information that gives an overview of the possible techniques to assess internal and external doses. *In vivo* and *in vitro* monitoring for the purpose of dose assessment, as well as biological dosimetry, should be performed by specialists. Detailed guidelines on methods and procedures are therefore not given here.

Direct measurements, *in vivo*, can be used to determine the body content and distribution of radionuclides that emit penetrating radiation [Table A13.1]. The measurement technique is quick and convenient such that it should be relatively easy to ensure subject cooperation and to avoid anxiety. Typical *in vivo* monitoring lasts from a couple of minutes to an hour and the results are available to the monitoring personnel immediately after the measurement. The minimum detectable activities (MDA) vary from some tens of becquerels (Bq) to thousands of becquerels depending on the radionuclide and measurement technique used as well as the measurement time. Before measurement, any external contamination needs to be removed to prevent further internal contamination of the person being measured, and to reduce errors in assessment of the internal contamination. The environmental background radiation is likely to be highly variable and must be taken into account in data analysis.

Three types of *in vivo* measurements may be necessary:
1. Whole body counting;
2. Organ or partial body counting;
   (thyroid, lung, liver, bone); and/or
3. Wound counting.

Detectors that could be used include [Annex 8]:
- Scintillation detectors;
- Semiconductor detectors;
- Gas filled detectors;
- Liquid scintillation detectors; and
- Gamma cameras.

In vitro monitoring is based on the determination of activity concentrations in biological samples excreted by or taken from the body.

If only α or β particles are emitted, or the yield or energies of any photon emissions are very low [Table A13.1] *in vitro* measurements will need to be performed. If *in vivo* monitoring facilities are not available *in vitro* methods may be employed. Radionuclides may first need to be separated from the sample matrix to achieve a good and reproducible measurement. If complicated radiochemical separation is needed before analysis (e.g. polonium, plutonium), the results are obtained only after some days - or even weeks. In the case of urine samples, however, direct dispersion of a small volume of the sample into a liquid scintillant or using ICP-MS techniques may be sufficient for rapid analysis. Radionuclides emitting penetrating photons can, in general, be quantified in bulk samples. Although these radionuclides may also be detectable in the body by *in vivo* counting, detection in excreta may be more practical or the only alternative if *in vivo* monitoring is not available.

There are no internationally agreed procedures for the assay of samples obtained for indirect assessment of levels of radionuclides in the body. The preference for a given procedure will depend on the equipment available, the samples to be analysed, their anticipated levels of activity and experience of the staff. Samples that can be used are [Annex 11]:
- Urine;
- Faeces;
- Blood; and
- Nasal swab.

In an accident situation, it is often not possible to reconstruct reasonably the absorbed dose on the basis of physical dosimetry, and biodosimetry is then the only option for characterising the exposure.

Biological dosimetry, or biodosimetry, is the measurement of radiation induced changes in human body for dose assessment. The term biological dosimetry encompasses cytogenetics, Electron Paramagnetic Resonance (EPR) biodosimetry with tooth enamel and other calcified tissues, mutation expression and DNA damage related assays, observation of symptoms and signs (clinical biological dosimetry), and bioassay.

All of the above methods have limitations related to detection limit, dose range applicable and, type of radiation, persistence of the marker, feasibility of measuring a large number of samples due to labour intensity and the need for expertise. Biological dosimetry by cytogenetic assays and EPR assays are discussed in more detail in Annex 9.

H.21 Whole body and organ monitoring

(CONTAMINATION INCIDENTS) (TACTICAL INCIDENT COMMAND [TIC])

1. Establish contact with the national internal dosimetry laboratory, or the laboratory that performs *in vivo* monitoring for your country, region or facility.
2. Notify the laboratory of the estimated number of subjects for *in vivo* monitoring.
3. Arrange transport for the subjects to the laboratory.
4. In consultation with the laboratory, establish:
   - The number of measurements per day that can be performed;
   - The time expected for reporting results; and
   - The minimum detectable activity or detection limit for the measurements to be performed.

Individual monitoring methods suitable for typical radionuclides are listed in Information H.13. Monitoring for internal contamination with dose rate meters and simple hand-held instruments is described in Section F.3.4.1.

H.22 *In vitro* monitoring

(CONTAMINATION INCIDENTS) (TIC)

1. Establish contact with the national bioassay laboratory or laboratory that performs the *in vitro* monitoring for your country, region or facility.
2. Notify the laboratory of the estimated number of samples.
3. Follow the instructions of the bioassay laboratory personnel to arrange collection and transportation of the urine, blood or faecal samples to the laboratory.
4. In consultation with the laboratory, establish:
   - The number of measurements per day that can be performed;
   - The time expected for reporting results; and
   - The minimum detectable activity or detection limit for the measurements to be performed.

Examples of minimum detectable activity (MDA) for detection of ^{137}Cs with gamma spectroscopy are about 0.1 Bq/l and for ^{90}Sr

Information H.21

Wound monitoring

Wound monitoring is done at hospitals often in connection with decontamination. Gamma contamination is easily detected, but beta contamination is more difficult. For detection of alpha contamination a special probe is required. This Handbook does not give special instructions for this kind of monitoring. The advice is to contact a specialist.

Information H.23

Biological dosimetry assays

The choice of assay method depends on the capacity and availability of assays in designated national laboratories, or networks of other laboratories and the usefulness of the technique for a given exposure. In most European countries, the best standardised method will be the dicentric assay and one can expect that triage dicentric assay will be the method applied for scenarios with many people in need of biological dosimetry. Countries with a standardised micronucleus assay analysis capability, may prefer to use this test, and possibly increase their capacity by employing other laboratories that use micronucleus assays for other purposes. In situations where clinical symptoms, like vomiting and white blood cells, indicate that the doses are in excess of the limit for dicentric and micronuclei assays, the premature chromosome condensation method (PCC) could be applied. There are few laboratories in Europe capable of doing this assay and they should be contacted via national or regional laboratories/authorities. The same applies to Electron Paramagnetic Resonance techniques.

"Triage" approaches using cytogenetic methods are the biological dosimetry approch of choise when there are many subjects to test.

The guidance for taking blood samples and transporting them to the laboratories are the same for all cytogenetic assays. Hospitals and health centres should have available stocks of sampling equipment and lithium heparin tubes. A large stock of such tubes could be needed for mass casualty situations.

Procedures should be available in advance for contacting the biological dosimetry laboratory, for taking blood samples and for logistic connected with the transport of blood. Special considerations have to be taken regarding transport conditions. All available exposure details, and information regarding blood collection and storage, should accompany the blood samples. (Continued over page)

0.1 Bq/l after radiochemistry and beta-measurement. Using radiochemical procedures and alpha spectroscopy the MDA for ^{238}U is about 0.1 mBq/l and for ^{210}Po 1 mBq/l. ICP-MS is a modern and more sensitive method for detection of long-lived alpha emitting radionuclides, but might not always be available. Remember the possibility of international assistance.

H.23 Biological dosimetry

(TIC)

1. Establish contact with the national biological dosimetry laboratory or the laboratory that performs the biodosimetry service for your country, region or facility (Laboratory preferably meeting the requirements of ISO 19238).
2. Notify the laboratory of the estimated number of subjects for biological dosimetry. In case of a great number of samples, consider in consultation with this laboratory, whether formal or informal networks for biological dosimetry by cytogenetics should be activated. Anticipate type of exposure (if possible).
3. Agree on the number of samples and on the arrangement for the delivery of the samples to the laboratory.
4. Take and transport the blood samples according to procedures described in Annex 11.

Information H.23 (cont.)

Biological dosimetry by cytogenetics

These techniques estimate the frequency of chromosomal aberrations i.e. the characteristic chromosome changes. Assays used are: metaphase spread dicentric assay, micronucleus assays, premature chromosome condensation (PCC) and fluorescent *in situ* hybridisation (FISH).

Countries with a developed nuclear power industry usually have biological dosimetry laboratories, but there are several countries without such facilities. It takes at least 3-4 days to get the result of counting from the time the blood sample enters the laboratory. All these methods demand special expertise and calibration curves for different type of radiations. The table below presents the main characteristics of cytogenetic biodosimetry methods. Further information is given in the Annex A9.

Table H2. Comparison of usefulness and limitations of different cytogenetic assays for acute biological dosimetry (based on BiodosEPR-2006 Meeting recommendations, Alexander et al, 2007).

	ASSAY			
CRITERION	Dicentric assay	Micronucleus assay (MN) (cytokinesis block micronucleus assay CBMN)	Premature chromosome condensation (PCC)	Fluorescent *in situ* hybridisation (FISH)
Dose range (Gy)	0.1 - 5	0.3 - 5	1 - 20	0.25 - 3
Sensitivity (Gy)	0.1	0.3	1	0.25
Time for taking samples after expose	≥ 24h	≥ 24h	≥ 24h	≥ 24h
	If sign and symptoms of expose occur within hours and other information of exposure indicates dose of several Gray, then take the sample as soon as possible (usually hospital patients)			
Triage approaches (mass casualty situation with more than ca. 20 samples during the first week in one lab)	Yes, but sensitivity is 1 Gy	Possible	Yes, but sensitivity is several Gy	Not applicable
How long the technique can be used after exposure? (Optimum time)	Days-weeks	Days-weeks	Hours- days	Retrospective
Standardisation of the assay	ISO standard	-	-	-
Usefulness for partial body exposure	Yes	No (some indications)	No data	Yes

4 Later triage and monitoring

Introduction

This section describes the later stages of radiological triage that would be carried out using information from initial individual monitoring [Section F.3]. Triage based on the results of monitoring is likely to take place after a Monitoring Strategy [Section H.2] as been established. The actions to be carried out for these triage groups, including additional monitoring, are briefly described. They are summarised in Figures H2 and H3, and Table H4.

H.24 **Symptoms of ARS**
(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)
If any individual exhibits symptoms of nausea, vomiting or diarrhoea during triage or monitoring, they should be referred immediately for medical assessment [Section J.4].

4.1 Action Levels

H.25 **Action Levels**
(TIC, LEADERS FOR RADIOLOGICAL TRIAGE, PEOPLE MONITORING, AND MEDICAL TEAMS)
Action Levels should be specified for decontamination, referral for medical assessment, additional monitoring, provision of information to individuals, and for inclusion in any programme of long-term follow up monitoring. Recommended Action Levels are given in the Tables in Annex 10 for the radionuclides listed in Table H1 [Information H.13 and H.14], for various times after acute exposure. For intermediate times, the higher value for the two adjacent times should be used. These Action Levels are directly related to dose, but are specified in terms of measured quantities so that direct comparison with the results of measurements can be made. An upper Action Level is associated with urgent actions, while a lower Action Level is associated with actions that are less urgent. Depending on the radionuclide, Action Levels are specified for:

Information H.25

Dose action levels
The upper dose action level for internal contamination, AL_U, is a fixed value that corresponds to a committed effective dose of **200 mSv**. This is the upper action level proposed by the TIARA project, (Menetrier et al, 2005), above which medical treatment to reduce doses (e.g. by decorporation) should be considered.

The upper dose action level for external contamination by beta-gamma emitters, AL_U, corresponds to an absorbed dose to the skin of **2 Gy** to an area of skin in excess of 600 cm^2. In comparison, IAEA recommends a Generic Reference Level for Medical Action of 10 Gy to an area of skin in excess of 600 cm^2 (IAEA EPR-Medical, 2005, Table F2, p. 104). In IAEA's recommended scheme, exceeding this action level would trigger immediate decontamination and immediate medical examination, consultation and treatment. A lower action level for external contamination is recommended here because there is evidence that a number of symptoms may appear at skin doses below 10 Gy, including initial transitory erythema, later transitory hair loss, secondary erythema and later hyper-pigmentation. It should be noted that exceeding the TMT Handbook action level would trigger immediate medical assessment, but is not intended to trigger medical treatment in itself.

Action Levels on measured quantities
The Action Levels presented in the Tables in Annex 10 are directly related to these dose action levels but are specified in terms of measured quantities. Action Levels for external contamination on skin and clothing were determined by direct application of the skin beta dose rate conversion factors contained in Table H7 [Information H.55]. Action levels for elapsed times after the contamination event of 12 hours and 1 day assume that contamination was present at a constant level until that time, and is then removed completely. These Action Levels may be taken to apply to contamination of both skin and clothing; no allowance is made for the effect of shielding in the latter case.

Action Levels for internal contamination were determined by carrying out bioassay calculations using current ICRP models and the default parameter values described in Table 1 of Annex 10. These calculations are not intended to provide an accurate assessment of the relationship between bioassay quantities and dose, because the parameter values used in the calculation may well differ significantly from values appropriate for a specific incident or exposure scenario. Nevertheless, the calculations should be adequate for the intended purpose; that is, to facilitate decisions about further actions. (Continued over page)

- External contamination measured on skin or clothing (Bq cm^{-2});
- Internal contamination measured in whole body, lungs or thyroid (Bq); and
- Measurements of activity in 24-hour urine samples (Bq d^{-1}).

Information H.25 presents the Action Level tables for inhalation of ^{90}Sr (Type F), inhalation of ^{131}I and ingestion of ^{137}Cs.

H.26 **Lower Action Levels**
(CONTAMINATION INCIDENTS) (TIC)
The ratio of the upper Action Level to lower Action Level (AL_U/AL_L) should initially be set at 10, but should be considered as a variable quantity, to allow demand for resources to be matched to their availability. A value of 10 is a minimum value. It is unlikely to exceed 200.

H.27 **Recommended actions**
(CONTAMINATION INCIDENTS) (TIC)
Recommended actions corresponding to these Action Levels are given in Table H4 [Information H.35].

H.28 **Action Levels for children**
(CONTAMINATION INCIDENTS) (TIC)
For children (below 16 years of age), the Action Levels determined for adults should be reduced by a factor of 10 to provide an adequate degree of conservatism in the initial stages of the response. These Action Levels may be revised subsequently, on the basis of more realistic dosimetric calculations appropriate for children. Such calculations are beyond the scope of this Handbook, and should be carried out by experts in internal dosimetry.

4.2 Triage after initial external contamination measurements

H.29 **Recommended actions**
(RADIOLOGICAL TRIAGE, DECONTAMINATION, PEOPLE MONITORING TEAMS)
The following actions should be carried out in the order of priority indicated by the measured external contamination levels. Unless

Information H.25 (cont.)

No action levels are provided for nose blow or nasal swab monitoring because the available techniques do not provide quantitative estimates of internal dose after inhalation. The results of such monitoring may, however, be used to help to prioritise people for more accurate measurements, such as those provided by lung monitoring. Detection of relatively high levels of activity on a nasal sample may be taken to indicate that the individual could be one of the more highly exposed. Failure to detect activity on a nose blow sample should never be taken to indicate that no intake has occured.

Three examples of Action Level tables (for inhalation of ^{90}Sr (Type F), inhalation of ^{131}I and ingestion of ^{137}Cs) are presented below.

Table H3. Action Levels (copy of tables from Annex 10.)
Copy of Table A10.5a. Action Levels for ^{90}Sr, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U/AL_L
			12 h	1 d	3 d	7 d	14 d	
Sr-90 Type F	External contamination	External scan	4.8E+04	2.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	4.5E+05	1.0E+05	4.2E+04	1.9E+04	10

(Continued over page)

there is unequivocal evidence that an irradiation source has remained sealed, the actions specified in Instructions H.30-H.34 should be carried out [Figure H2].

H.30 **Actions when the measurement (M) > AL_U**
(RADIOLOGICAL TRIAGE, MEDICAL, DECONTAMINATION TEAMS)
If an individual has contamination levels on skin or clothing above the Upper Action Level, AL_U, [Annex 10], then carry out actions 1, 2, 3, 4 and 8 in Table H4 [Information H.35], take a blood sample for CBC, and refer the individual immediately for medical assessment [Section J.4].

H.31 **Actions when AL_U > M > AL_L**
(RADIOLOGICAL TRIAGE, DECONTAMINATION, PEOPLE MONITORING TEAMS)
For individuals with contamination levels between the Upper and Lower Action Levels AL_U and AL_L [Annex 10], carry out actions 5, 6 and 8 in Table H4 [Information H.35].

H.32 **Actions when M < AL_L**
(RADIOLOGICAL TRIAGE TEAM)
For contaminations levels below the Lower Action Level AL_L [Annex 10], then carry out actions 7 and 8 in Table H4 [Information H.35].

H.33 **Selection for rapid internal contamination monitoring**
(RADIOLOGICAL TRIAGE TEAM)
People with contamination levels above the Lower Action Level AL_L should be selected for initial internal contamination monitoring [Section F.3.4]. These people should be monitored in the order of priority determined by their measured external contamination level. Where people have similar measured external contamination levels, those with contamination on the face should be assigned a higher priority, as this could indicate that inhalation of contaminated material has taken place.

Information H.25 (cont.)

Copy of Table A10.8a. Action Levels for ^{131}I, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
I-131 Type F	External contamination	External scan	1.0E+05	5.2E+04	-	-	-	10
	Internal contamination - rapid initial screening	Thyroid (rapid)	1.7E+06	2.3E+06	2.1E+06	1.4E+06	7.3E+05	10
	Internal contamination - primary monitoring method	Thyroid	1.7E+06	2.3E+06	2.1E+06	1.4E+06	7.3E+05	10

Copy of Table A10.10b. Action Levels for ^{137}Cs, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cs-137	External contamination	External scan	1.0E+05	5.2E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.5E+07	1.5E+07	1.4E+07	1.3E+07	1.2E+07	10
	Internal contamination - primary monitoring method	Whole body	1.5E+07	1.5E+07	1.4E+07	1.3E+07	1.2E+07	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1}).
Dose calculations were performed using the same assumptions as specified in Annex 13.

Information H.28

Action Levels for children
In some cases, the value of the committed effective dose assessed from a unit measurement value is significantly greater for a child than for an adult. Action Levels for children should be reduced by a factor of 10 until dose per unit measurement calculations have been carried out for children of different ages.

H.34 **Long-term follow up**

(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAM)

People above the Lower Action Level AL_L should be included in any programme of long-term follow up monitoring. People below the Lower Action Level AL_L may be considered for inclusion in any programme of long-term follow up monitoring [Section K.9].

4.3 Triage after initial internal contamination measurements

H.35 **Recommended actions**

(RADIOLOGICAL TRIAGE, MEDICAL AND PEOPLE MONITORING TEAMS)

The following actions should be carried out in the order of priority determined by the measured internal contamination levels. Unless there is unequivocal evidence that an irradiation source has remained sealed, the specified actions in Instructions H.36-H.41 should be carried out (Figure H3).

H.36 **Actions when $M > AL_U$**

(RADIOLOGICAL TRIAGE, MEDICAL AND PEOPLE MONITORING TEAMS)

If rapid measurements of internal contamination levels indicate that the upper Action Level, AL_U, is exceeded [Annex 10], then carry out actions 9, 10, 11 and 14 in Table H4.

H.37 **Prioritisation for more accurate internal contamination monitoring, $M > AL_U$**

(PEOPLE MONITORING TEAM)

If AL_U is exceeded, more accurate internal contamination measurements should be carried out as soon as possible (1ST MONITORING PRIORITY) [Section H.4.1].

H.38 **Prioritisation for more accurate internal contamination monitoring, $AL_U < M < AL_L$**

(PEOPLE MONITORING TEAM)

If rapid measurements of internal contamination levels give a result between the upper and lower Action Levels, AL_U and AL_L, [Annex

Information H.35

Table H4. Actions corresponding to the Action Levels of Annex 10.

Action level on:	Measurement, M	Actions
External contamination	$M > AL_U$	1. Remove contaminated clothing immediately. 2. Carry out urgent decontamination followed by re-monitoring [Section G.2]. 3. Commence blood sampling for CBC . 4. Refer individual immediately for medical assessment [Section J.4].
	$AL_U > M > AL_L$	5. Carry out decontamination procedures on individuals in priority order [Section G.2].
	$AL_U > M > AL_L$	6. Include in any programme of long-term follow up monitoring [Section K.9]. Carry out rapid initial screening for internal contamination, in priority order.
	$M < AL_L$	7. Instruct individuals to return home and carry out simple decontamination procedures there [Section G.3].
	All measurement values	8. Provide information to individual on measured external contamination levels and any associated dose and risk assessments[1] [Annex 3 and Chapter D].
Internal contamination -rapid initial screening	$M > AL_U$	9. Carry out measurements with primary monitoring method urgently. 10. Refer for medical assessment [Section J.4]. 11. Commence blood sampling for CBC and cytogenetic measurements.
	$AL_U > M > AL_L$	12. Carry out measurements with primary monitoring method in priority order.
	$M < AL_L$	13. Consider for inclusion in any programme of long-term follow up monitoring [Section K.9].
	All measurement values	14. Provide information to individual on measured internal contamination levels and associated dose and risk assessments[1] [Annex 3 and Chapter D].
Internal contamination -primary monitoring method	$M > AL_U$	15. Refer for medical assessment [Section J.4]. 16. Commence blood sampling for CBC and cytogenetic measurements if not already started.
	$AL_U > M > AL_L$	17. Include in any programme of long-term follow up monitoring [Section K.9].
	$M < AL_U$	18. Consider for inclusion in any programme of long-term follow up monitoring [Section K.9].
	All measurement values	19. Provide information to individual on measured internal contamination levels and associated dose and risk assessments[1] [Annex 3 and Chapter D].

Notes.
1. Information provided will depend on the Action Level band in which the measurement value falls.

10], more accurate internal contamination measurements should be carried out as soon as possible (2ND MONITORING PRIORITY) and action 14 in Table H4 should be carried out [Section H.4.1].

H.39 Prioritisation for more accurate internal contamination monitoring, M < AL_L

(RADIOLOGICAL TRIAGE TEAM)

Remaining individuals should be prioritised for more accurate internal contamination measurements (3RD MONITORING PRIORITY) and action 14 in Table H4 [Information H.35] should be carried out [Section H 4.1].

H.40 Recommended actions

(RADIOLOGICAL TRIAGE, MEDICAL, PEOPLE MONITORING TEAMS)

Actions 15, 16, 17, 18 or 19 should be carried out, as required [Table H4, Information H.35], on the basis of the results of these more accurate internal contamination measurements.

H.41 The TIARA method

(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)

The simple graphical method developed for the TIARA project should be used as an input to decisions on decorporation treatment based on the results of these more accurate internal contamination measurements. The method applies where intakes occurred by inhalation and is described in Annex 7. Instruction H.42 explains how to use the method.

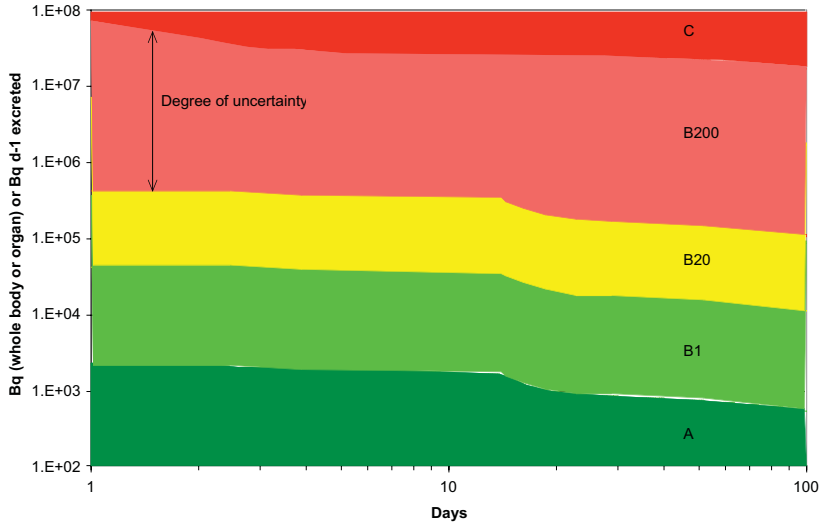
H.42 Using the TIARA method

(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)

Select the appropriate figure for the radionuclide and monitoring method from the TIARA booklet "Dose Assessment of Inhaled Radionuclides in Emergency Situations". An example figure is shown in Information H.4.1.

Use the measurement value and the elapsed time of the measurement or sample after intake to determine the colour band (also labelled A, B1, B20, B200 and C) in which the result lies.

Information H.41



Notes
1. The y-axis shows the measured amount of the radionuclide in whole body or organ of the body, expressed in Bq, or the measured amount of the radionuclide excreted in urine or faeces per day, expressed in Bq d^{-1}.
2. The x-axis shows the elapsed time of the measurement or sample after intake.
3. This example is for whole-body measurements of ^{137}Cs.

Figure H1. The TIARA method (Menetrier et al, 2007b).

For results in the red bands (B200 or C), with an estimated committed effective dose of 200 mSv or greater, treatment should be considered. However, psychological factors and the potential efficacy of extended or protracted treatment should also be considered [Instructions J.24 and J.25].

For results in the yellow band (B20), with an estimated committed effective dose between 20 and 200 mSv, treatment should be subject to medical judgement. Although clinical effects are unlikely to occur, the potential efficacy of initial short-term treatment should be considered [Instructions J.24 and J.25].

For results in the green band (B1), with an estimated committed effective dose between 1 and 20 mSv, more accurate dose assessment is required. Treatment does not need to be considered [Instructions J.24 and J.25].

For casualties in the green band (A), with an estimated committed effective dose below 1 mSv, treatment does not need to be considered. No further dose assessment is required.

H.43 Demand exceeds capacity

(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)

If numbers requiring monitoring exceed the immediately available capacity, then smaller numbers of people who are representative of the various groups identified in the triage process may be monitored [Section H.2.3].

H.44 Action Level for stable iodine treatment

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

No action level is proposed for use of stable iodine for thyroid blocking. National guidelines for the use of stable iodine should be followed.

H.45 Action Level for Prussian Blue treatment

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

If the incident involves exposure to ^{137}Cs, and internal contamination monitoring measurements indicate that the projected dose would be greater than 20 mSv, then these individuals should

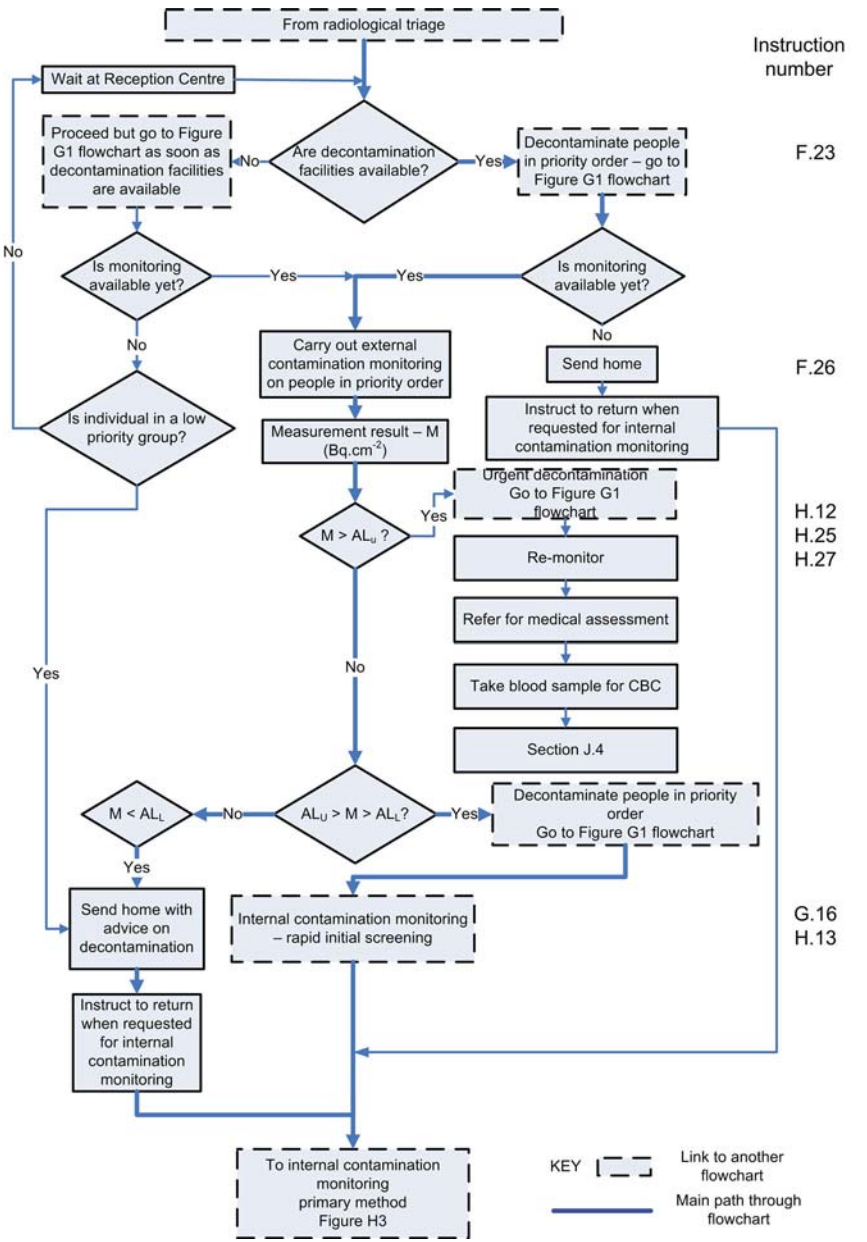


Figure H2. Flowchart for radiological triage based on results of external contamination monitoring.

be considered for treatment with Prussian Blue [Section J.8]. A projected dose of 20 mSv should be treated as a guideline value which may be varied according to circumstances. Any treatment must always be subject to medical judgement on a case-by-case basis.

H.46 **Action Level for DTPA treatment**

(RADIOLOGICAL TRIAGE, MEDICAL TEAMS)

If the incident involves exposure to plutonium, americium or californium, please refer to the TIARA method [Instruction H.41] for consideration of treatment with DTPA [Section J.8]. Any treatment must always be subject to medical judgement on a case-by-case basis.

H.47 **Long-term follow up**

(RADIOLOGICAL TRIAGE, PEOPLE MONITORING TEAMS)

People above the Lower Action Level AL_L should be included in any programme of long-term follow up monitoring. People below the Lower Action Level AL_L may be considered for inclusion in any programme of long-term follow up monitoring [Section K.9].

4.4 Triage after cytogenetic measurements

H.48 (PEOPLE MONITORING TEAMS)

Determination of the presence and frequency of chromosome aberrations provides a more accurate dose assessment method than that obtained from measurements of blood cell depletion kinetics based on complete blood counts (CBC) [Section J.10]. However, results are unlikely to be available until 4 to 5 days after the incident. The technique is therefore likely be used to confirm or refine dose estimates obtained from CBC, external contamination and internal contamination measurements.

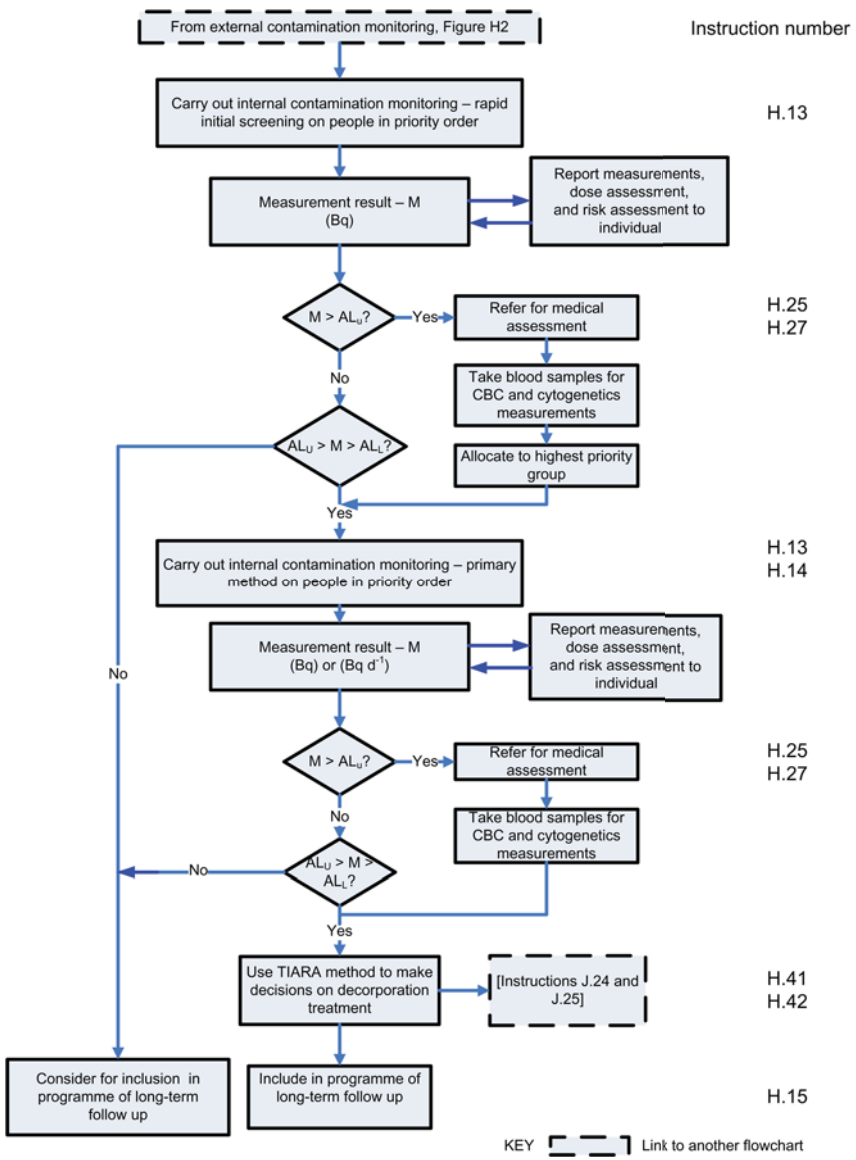


Figure H3. Flowchart for radiological triage based on results of internal contamination monitoring.

5 Dose assessment methods

Introduction

This section addresses the retrospective assessment of doses to individuals. Doses may result from:

- Internal contamination following inhalation or ingestion of radioactive material;
- External contamination resulting from deposition of radioactive material on the skin and/or clothing; and/or
- External irradiation resulting from proximity to a radioactive source.

Scope

Assessment of doses resulting from internal contamination

Retrospective assessment of internal doses makes use of measurements of the activities of radionuclides in the body (measured in becquerels, Bq) or in excreta (measured in Bq d^{-1}). Internal dose assessment is a complex subject. This section does not attempt to present comprehensive guidance for the accurate assessment of internal doses, for which expert guidance must be sought (see, for example, ICRP Publication 78, 1997). Rather, information is presented that will allow simple and approximate calculations to be carried out using default model parameter values.

Results of these calculations will inform decisions on the need for additional and/or more accurate monitoring and more accurate dose assessments. In the early stages of the response, the main requirement is to be able to make such decisions rapidly, and approximate results are adequate for this purpose. In fact, it is likely to be counter-productive to attempt to achieve higher levels of accuracy, because this will require a considerable effort and the expenditure of scarce resources. In many cases, individual doses are likely to be low enough that an approximate assessment is all that is required.

Information Section H.5

Topics not covered in this section

Assessment of doses resulting from external irradiation is not addressed in any detail in this section because these doses are measured directly by dose rate monitoring equipment and by biological dosimetry.

The detailed reconstruction of doses based on information on the movements of individuals at the time of the incident is beyond the scope of this Handbook.

The assessment of doses based on the results of biological dosimetry techniques is described in [Section J.10].

Once the emergency phase is over, expert advice should be obtained, in order to improve the accuracy of dose assessments. Furthermore, if approximate dose assessments indicate that there may be a significant risk to the health of an individual, then advice should be obtained immediately from experts in internal dosimetry to improve the accuracy and reliability of dose estimates.

Assessment of doses resulting from external contamination
In general, it is the dose to the skin that is of most concern when a person is externally contaminated. Retrospective assessment of skin dose makes use of measurements of the activities of radionuclides on the skin (measured in Bq cm^{-2}). Where doses to the skin are very high, assessment of doses to internal organs may also be required.

Assessment of doses resulting from external irradiation
Retrospective assessment of doses resulting from external irradiation presents a significant challenge. Where exposure is high enough to cause deterministic effects, doses may be estimated from observations of clinical symptoms; however, dose assessment is of secondary concern for such cases. Where whole body (WB) exposures are potentially in excess of about 0.5 Gy, complete blood counts (CBC) may provide an estimate of dose. For WB exposures in excess of about 0.1 Gy, biodosimetry techniques [Section J.9 and Annex 9] may allow doses to be assessed. However, for potential exposures below 0.1 Gy, no established techniques exist. Doses can only be estimated, rather than assessed, based on information derived from environmental monitoring results and modelling. Some guidelines are presented in Information H.64.

5.1 Internal dose assessment

H.49 **Dose assessment data**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENTS TEAM)
The tables presented in Annex 13 should be used to determine the committed effective dose to age 70 y for all those for whom internal contamination monitoring has been carried out. This Annex contains look-up tables that allow measurements of activity in

Information H.50

The default daily urine volumes are those recommended by ICRP in ICRP Publication 89, 2003.

Information H.51 and H.52

It is preferable that dose assessments are based on 24 hour urine samples. This avoids the variability that can arise from the use of single voiding (i.e. “spot”) samples, and the uncertainties that are associated with the use of any normalisation method. 24 hour sampling is preferable to normalisation by volume, because of the large inter-subject variation in daily urine volume.

Information H.52

ICRP states that “the restrictions on effective dose are sufficient to ensure the avoidance of deterministic effects on all body tissues and organs, except the lens of the eye ..., and the skin which may well be subject to localised exposures” (ICRP Publication 60, 1991). Thus, it can be assumed that deterministic effects to all organs except to skin and the lens of the eye will not occur if the occupational dose limit of 20 mSv has not been exceeded.

Information H.52 and H.54

If the committed effective dose exceeds 200 mSv, the individual should already have been referred for medical assessment if the guidelines regarding Monitoring Strategy have been followed [Section H.2]. Where the committed effective dose is in excess of 20 mSv the need for medical assessment should have been considered [Section H.2].

whole body, lungs, thyroid on urine to be converted to dose. Data is presented for both inhalation and ingestion of all of the radionuclides in Table H1 [Section H.2.5]. For whole body, lung and thyroid, the tables contain data for measurements made during the period 6 hours to 28 days after an acute intake. For urine measurements, the tables contain data for urine samples taken during the period 1 – 28 days; it is assumed that 24 hour samples would be taken, so no samples would be available for sample times less than 24 hours [Section H.4.3].

H.50 **Normalisation of urine measurements**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
If the urine sample was not collected over a 24 hour period, then the measurement should be normalised according to volume by multiplying the measured value by (V_{24}/(volume of urine sample (litres))). V_{24} is equal to 1.6 litres for men, and 1.2 litres for women. The volume of the sample should be measured at the time of receipt of the sample [Section H.4.3].

H.51 **Alternative normalisation method**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
An alternative is to normalise the measurement by multiplying the measured value by (24/[time period of sample (h)]). This is appropriate if the sample was collected for a period that is close to 24 hours. Information on the start time and end time of the urine sample should have been obtained from the individual providing the sample [Section H.4.3].

H.52 **Assessment of absorbed doses to organs**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
If the assessed committed effective dose summed for internal and external exposure is > 20 mSv, then the RBE-weighted absorbed doses to the lungs, red bone marrow and colon should also be assessed using the tables in Annex 13.

H.53 **Assessment of absorbed doses to the thyroid**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
The exception to Instruction H.52 arises when the contaminant radionuclide is a radio-iodine isotope. For ^{131}I exposures, the

Information H.52 and H.53

Relative Biological Effectiveness (RBE)
The following values have been used in the calculation of RBE-weighted absorbed dose in Annex 13.

Table H5. Relative Biological Effectiveness (RBE) for severe deterministic effects.

Radiation	RBE
Gamma-radiation & X-radiation	1
Beta particles	1
Alpha particles irradiating lungs	7
Alpha particles irradiating red bone marrow	2
Alpha particles irradiating colon	0
Iodine-131 irradiating thyroid	0.2

(IAEA EPR-Medical, 2005, Table F1).

Information H.54

The RBE-weighted absorbed organ dose is used to assess the likelihood and magnitude of deterministic effects on those organs. If the values in Table H6 are exceeded, then the person should be referred immediately for medical assessment and consideration for treatment, decorporation therapy or prescription of stable iodine as appropriate.

Table H6. Generic reference levels on RBE-weighted absorbed dose.[1]

Organ	RBE-weighted absorbed dose (Gy-Eq)[2]
Red marrow (intakes of actinides)	0.2
Red marrow (intakes of other radionuclides)	2
Thyroid[3]	2
Lung	30
Colon	20

Notes
1. From IAEA EPR-Medical, 2005, Table F2.
2. Integration period = 30 d.
3. For use only when the thyroid is the critical organ.

RBE-weighted absorbed dose to the thyroid should be assessed using the tables in Annex 13.

H.54 **Provision of dose assessment results to medical staff**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
Where the assessed committed effective dose exceeds 200 mSv, then the individual should have been referred immediately for medical assessment [Section H.4.1]. Full information on the assessed RBE-weighted absorbed organ dose should be provided to the relevant medical staff [Instructions J.6, J.24 and J.25]. This information should be regularly updated as additional monitoring data is obtained and improved dose assessments carried out.

5.2 Assessment of dose to the skin resulting from external contamination

H.55 **Calculation of dose rate to skin**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
Dose rates to the skin should be calculated using the conversion factors in Table H7.

H.56 **Skin dose**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
The actual or projected dose to an area of skin should be determined by integrating the assessed dose rate to that area of skin over the period during which the contamination was present, or is expected to be present.

H.57 **Provision of dose assessment results to medical staff**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
If the assessed dose to an area of skin in excess of 600 cm^2 could exceed 2 Gy, then the individual should have been referred immediately for medical assessment [Section H.4.1 and Section J.4] if not already done, and full information on assessed skin and internal doses should be provided to the relevant medical staff. Further decontamination is urgently required [Section F.2 and Section G.2].

Information H.55

Table H7. Skin beta dose rate conversion factors for material deposited on skin or clothing.

Radionuclide	Conversion factor ($\mu Sv\ h^{-1}$)/($Bq\ cm^{-2}$)	Radionuclide	Conversion factor ($\mu Sv\ h^{-1}$)/($Bq\ cm^{-2}$)
Manganese-54	0.062	Europium-152	0.92
Cobalt-60	0.78	Europium-154	2.1
Selenium-75	0.14	Iridium-192	1.9
Strontium-90/ Yttrium-90	3.5	Polonium-210	6.9E-7
Silver-110m	0.68	Radium-226	no value given
Cadmium-109	0.54	Plutonium-238	3.7E-3
Iodine-131	1.6	Americium-241	0.019
Barium-133	0.13	Californium-252	3.2E-3
Caesium-137	1.6		

Note: The dose rates are to the basal layer of the skin (70 μm in depth) due to beta rays and electrons. The gamma contribution to the dose rate is generally just a few per cent. Contamination is supposed to be uniformly spread over the skin (infinite thin deposit).

With the exception of contamination by alpha or neutron emitters, the dose equivalent to the skin expressed in Sv is equal to the absorbed dose expressed in Gy. For alpha emitters, the dose to the basal layer of the skin is zero. For neutron irradiation, expert advice must be sought.

For an initial dose estimate, no correction should be made for the shielding effect of clothing. Be aware, however, that doses to skin may then be substantially overestimated.

If a mixture of radionuclides is present, gamma spectrometry on wipe samples must be employed to determine radionuclide-specific concentrations on the skin.

Taken from IAEA TECDOC 1162, 2000, Table E5.

Refer to Table E5 in IAEA TECDOC 1162, 2000, if the radionuclide encountered is not included in the above table.

5.3 Issues for consideration when performing more accurate assessment of internal dose

H.58 **Assumed time of exposure**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
If the exact time of exposure is unknown, or if the exposure could have been protracted over time, then it should be assumed that the exposure took place at the earliest possible time, based on specific information about the incident.

H.59 **Inhaled particle size assumptions**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
It is reasonable to make the initial assumption that, at the time of the incident, particle sizes close to the site of an incident (e.g. within the area affected by blast) are characterised by an Activity Median Aerodynamic Diameter (AMAD) of 5 µm and a geometric standard deviation (gsd) of 2.4. Similarly, it can be assumed that particle sizes further from the site of the incident are characterised by an Activity Median Aerodynamic Diameter (AMAD) of 1 µm with the same gsd.

H.60 **Realistic particle size distributions**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
However, be aware that that particle size distributions, particularly close in to the site of an explosion or fire, may be very broad. The effect on assessed doses (particularly doses to the respiratory tract) of making different assumptions about particle size distribution should be investigated to give an indication of uncertainties in dose estimates. More realistic information on the actual particle size distribution must be used if this becomes available.

H.61 **Absorption assumptions**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM)
It is reasonable to make the initial assumption that the absorption behaviour of the material containing the radionuclide (i.e. its "solubility") can be characterised by the ICRP default absorption type and gastro-intestinal uptake factor (Table H8). However, it cannot necessarily be assumed that the chemical form will be the

Information H.61

Assumptions about absorption behaviour ("solubility")
It is quite possible that radionuclides that are quite soluble when they are present as a pure chemical compound (e.g. ^{137}Cs, which is usually encountered as a salt such as caesium chloride) may be much less soluble when they are bound to refractory materials as may happen during an explosion or fire.

Information H.62a

Assumptions about particle size distribution
An AMAD of 5 µm is assumed for inhalation exposures close to the site because it is the default for exposures in the workplace, where exposed people are likely to be close to the source of airborne material. An AMAD of 1 µm is assumed for inhalation exposures more distant from the site because it is the default for environmental exposures. A particle size distribution characterised by an AMAD of 1 µm is more typical of the ambient aerosol, to which radionuclides may become attached at sites of exposure far from the original source.

Information H.62b

For very soluble materials, the choice of pathway does not have a significant effect on dose. For less soluble materials, the choice of pathway may have a significant effect. For example, assuming inhalation rather than ingestion may result in a significant increase in the assessed lung dose.

same as that considered in ICRP publications. More realistic assumptions about absorption behaviour may result in more accurate dose assessments. Expert advice should be sought on the chemical form of the material to which people were exposed. The effect on assessed doses of making different assumptions about absorption behaviour should be investigated, to give an indication of uncertainties in dose estimates.

H.62 **Intake route in the event of explosion, fire or airborne dispersal**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM).
If the incident involved explosion, fire or dispersal of airborne material, then the intake route should be assumed to be inhalation.

H.63 **Intake route in the event of food and water contamination**
(CONTAMINATION INCIDENTS) (DOSE ASSESSMENT TEAM).
If the incident involved deliberate contamination of food or water, then the intake route should be assumed to be ingestion, except for people who were close to the original site of contamination, where inhalation may also have taken place.

If the incident does not fall into one of these established categories, and/or if information on exposure conditions is incomplete, then a combination of inhalation and ingestion should be assumed, with the proportions reflecting the probability of each pathway.

5.4 Estimation of dose from external irradiation

H.64 **Estimation of external dose**
(EXTERNAL IRRADIATION INCIDENTS) (DOSE ASSESSMENT TEAM).
If projected whole body dose could be in excess of 0.5 Gy, then complete blood counts should be initiated and the results used to provide an estimate of dose [Annex 5]. If projected whole body dose could be in excess of 0.1 Gy, then biological dosimetry procedures [Annex 9] should be considered. To estimate lower whole body doses, information from a number of sources will need to be collected:

Information H.61

Table H8. Radiation emissions, absorption types and gastro-intestinal uptake factors f_1 for intake by inhalation.

Radionuclide		Radiation type	γ energy[1] (keV)	Absorption types	f_1	Compounds
Manganese-54	^{54}Mn	γ (EC)	835 (100 %)	F M	0.1 0.1	Unspecified compounds Oxides, hydroxides, halides, nitrates
Cobalt-60	^{60}Co	β, γ	1332 (100 %) 1173 (100 %)	M S	0.1 0.05	Unspecified compounds Oxides, hydroxides, halides, nitrates
Strontium-90	^{90}Sr	β	-	F S	0.3 0.01	Unspecified compounds strontium titanate
Selenium-75	^{75}Se	γ (EC)	136 (61 %) 265 (59 %) 280 (25 %)	F M	0.8 0.8	Unspecified inorganic compounds Elemental selenium, oxides, hydroxides and carbides
Silver-110m	^{110m}Ag	β, γ	658 (95 %) 885 (73 %) 937 (34 %)	F M S	0.05 0.05 0.05	Unspecified compounds & metallic silver Nitrates and sulphides Oxides and hydroxides
Cadmium-109	^{109}Cd	γ (EC)	88 (3.6 %)	F M S	0.05 0.05 0.05	Unspecified compounds Nitrates, halides, sulphides Oxides and hydroxides
Iodine-131	^{131}I	β, γ	365 (81 %) 637 (7 %) 284 (6 %)	F	1	All compounds
Barium-133	^{133}Ba	γ (EC)	356 (62 %) 81 (34 %) 303 (18 %)	F	0.1	All compounds
Caesium-137	^{137}Cs	β, γ	662 (85 %)	F	1	All compounds
Europium-152	^{152}Eu	β, γ, β^+	122 (28 %) 344 (27 %) 1408 (21 %)	M	5E-4	All compounds
Europium-154	^{154}Eu	β, γ	123 (41 %) 1274 (36 %) 723 (20 %)	M	5E-4	All compounds
Iridium-192	^{192}Ir	β, γ	317 (83 %) 468 (48 %) 308 (30 %)	F M S	0.01 0.01 0.01	Unspecified compounds Metal, halides, nitrates Oxides and hydroxides
Polonium-210	^{210}Po	α	-	F M	0.1 0.1	Unspecified compounds Oxides, hydroxides, nitrates
Radium-226	^{226}Ra	α	186 (3.3 %)	M	0.2	All compounds
Plutonium-238	^{238}Pu	α	-	M S	5E-4 1E-5	Unspecified compounds Insoluble compounds
Americium-241	^{241}Am	α, γ	59.5 (36 %) 26.3 (2.4 %)	M	5E-4	All compounds
Californium-252	^{252}Cf	α	-	M	5E-4	All compounds

1. The three most intense gamma lines with yields > 1 % are listed, in order of intensity (ICRP Publication 38, 1983).
Recommended absorption types and f_1 values are taken from ICRP Publication 68, 1995, Annex F.

- Information on location of individuals collected for radiological triage purposes [Section F.2.2.1];
- Results of surveys of dose rate near the source of irradiation [Section F.3.2];
- Information on the location of the source (and its distribution, if material was dispersed); and
- The identity of the radionuclide and the activity of the source.

Information H.64 provides some proposals on how this information could be used.

Information H.64

In principle, the process of estimation of external dose to affected individuals requires:

1. A three-dimensional map of the dose rate as a function of time in the space through which the individual has moved.
2. A description of the path that the individual has taken through this space, expressed as a function of time.

The dose received by the individual could then be determined by calculating the time-integral of the dose rate along the path taken. However, difficulties are likely to arise because of the limited extent or accuracy of these two types of information.

Dose rate information may be obtained from direct measurements made with monitoring instruments, or from calculations based on the activity of the source and data on the shielding effect of material in the vicinity of the source. Optically-stimulated luminescence (OSL) measurements on irradiated materials may also provide useful data on cumulative dose over a period of time although, at present, this is more a research technique than a technique for dose reconstruction.

Information on location of individuals taken for radiological triage purposes will prove to be useful for dose estimation, although it is likely that more accurate information will eventually be needed. However, it has to be recognised that the accuracy of such information will always be less than ideal.

If large numbers of people must be considered, it is possible that dose estimation may need to be performed for groups of people, rather than individuals. Furthermore, it may not be possible to identify all potentially affected individuals. In this case, it may be necessary to estimate doses to hypothetical individuals and issue statements such as “People who were at location X for Y minutes may have received a dose up to Z Gy. Such a dose would result in a risk of long-term health effects equivalent to .....(e.g. number of chest X-ray procedures).....”.

6 Recording and reporting results

Introduction

The purpose of record keeping is to record, in chronological order, everything that has been done and everything that has been produced by the different teams, for later processing. For this, a database should be prepared in advance so that it is immediately available when needed. The records should include all the results from monitoring, analyses and assessments [Instructions F.54 and F.72]. The nature and scope of the records, and the extent of record keeping systems, depend in part on national requirements and standards. Examples of forms for recording and for reporting results are given in Annex 3.

The recording procedure for incidents needs to be prepared in advance. Details specifying the incident must be added to the appropriate national templates. For the recording of monitoring and analysis results for people, the minimum information should include the unambiguous identification of the person and of samples taken from that person, documentation of the monitoring procedure, analytical procedures employed, measured activity for each analysed radionuclide and any comments on the analyses that might be helpful in the interpretation of the results. The identity of the analyst should always also be recorded. It would be useful to emphasise results exceeding specified recording or investigation levels.

Several different types of reporting are needed. For general reporting every organisation should have its own procedures. Reporting is needed within organisations, between different organisations and authorities, directly to individuals, to the media etc. Some examples of forms and leaflets are given in Annex 3.

For reporting individual monitoring results, procedures specified by national bodies and regulatory authorities should be followed. The information that should be reported to individuals should be clearly identified and communicated in an understandable way to the lay man.

H.65 Collection of information

(RECORDS TEAM)

Records should be kept of people who are monitored and/or decontaminated. These records will be used to contact people who require short-term medical follow up, or for purposes of long-term health monitoring. Workers who responded to the incident and who were potentially contaminated should be included.

The following information should be collected:

- Information required from people involved in the accident;
- Information for medical facilities receiving contaminated casualities; and
- Information to be collected from contaminated casualities.

H.66 Confidentiality

(RECORDS TEAM)

All data and information that identifies individuals (known as person-identifiable information, PII) should be treated as confidential. It is recommended that the following principles governing the use of PII should be adopted:

- The purpose for which PII is being used should be justified;
- PII should not be used unless absolutely necessary;
- PII should be the minimum necessary;
- Access to PII should be on a strict "need to know" basis;
- All those who have access to PII should be aware of their responsibilities; and
- All those who have access to PII should understand and comply with the relevant laws of their country.

It is recommended that the following principles of data protection should also be adopted:

- Personal data should be processed fairly and lawfully;
- Personal data should be obtained for one or more specified and lawful purposes and should not be further processed in a manner incompatible with those purposes;
- Personal data should be adequate, relevant and not excessive in relation to those purposes;

Information H.65

At various stages during the response, information of various types will need to be collected from people affected by the incident. This information may be collected as part of the field triage process, or in order to help interpret the results of individual monitoring, or because it will be needed by a receiving medical facility. It is important that the information collection process is well-organised, avoids duplication, and avoids collection of unnecessary information. It is also important that an effective system is put in place to organise this information.

Information H.66

Some guidelines for using PII during an emergency are presented below:

- Ensure minutes of meetings do not use the names of individuals;
- Team members keeping their own records should be aware of the principles governing the use of PII;
- Papers containing PII should be stored securely after use;
- Databases containing PII must be password-protected;
- Laptops should have encrypted hard drives;
- Take care when giving information over the telephone, especially when dealing with the press; and
- PII should only be shared with other organisations when this is required in order to protect health, but sharing should be authorised by a senior member of staff.

(Caldicott report, 1997)

- Personal data should be accurate and kept up-to-date;
- Personal data should not be kept longer than is necessary for that purpose;
- Personal data should be processed in accordance with the rights of the person;
- Appropriate measures should be taken against unauthorised or unlawful processing of personal data and against accidental loss, destruction or damage; and
- Personal data shall not be transferred to countries outside the EU without adequate protection.

CHAPTER I

Handling of contaminated casualties and transport to hospital

Introduction

This section provides instructions on how to handle contaminated and uncontaminated persons and transport them from the site of the incident to the hospital.

I.1 **Notifying the radiation emergency department of the hospital about the transport of patients**
(AMBULANCE TEAM)

1. Provide information to the receiving hospital about the event, location and type of scenario, risk of radioactive contamination, nature of the possible contaminant/s (if known) and the number of patients to be transported.
2. For each patient, notify the receiving hospital of his/her medical status, actions taken at the scene (e.g. on site treatment/s, sampling), estimated time of arrival, risk of patient contamination and need for monitoring of the ambulance and its medical team.
3. All the relevant information should be recorded and travel with the victim, e.g. name, age, unique person code (if one has been assigned), circumstances of the incident (location, time, scenario), most likely pathways for exposure, radionuclide/s potentially involved, conventional injuries, medical problems beyond radiation exposure, actions taken on site.
4. Ask for any special instructions the hospital may have.

Information Chapter I

Handling casualties

Casualties require different handling depending on the radiation exposure.

Physically injured and known not to be contaminated or to have received a significant dose from external irradiation
These people do not require special facilities relating to radiation. They present no hazard to other people.

Physically injured and contaminated or potentially contaminated
These people may have radioactive material on their skin or clothing or may have inhaled or ingested radioactive material. Transfer of contamination may incur a small risk to other people. Precautions should be taken to reduce the spread of contamination to other people, vehicles and treatment facilities. The casualty's clothing, dressings, swabs and excreta should be bagged and labelled and retained for analysis [Section H.3]. Radiation monitoring, and possibly decontamination facilities, will be required [Section F.3.3 and Chapter G].

Casualty exposed to a high radiation dose, whether physically injured or not
Unless they are also externally contaminated, they present no hazard to other people, and there is no risk of contamination of vehicles or treatment facilities.

Uninjured but contaminated, or potentially contaminated
Radiation monitoring, and possibly decontamination facilities, will be required [Section F.3.3 and Chaper G]. It is possible that contamination alone, without physical injury or a significant dose from external radiation would be sufficient to cause deterministic effects in the casualty, but is unlikely to cause adverse effects on health for other people.

I.2 Transporting uncontaminated casualties with conventional injuries and/or external exposure to the hospital

(AMBULANCE TEAM)

Apply the conventional procedures for transport in an ambulance.

I.3 Transporting contaminated casualties with conventional injuries and/or external exposure to the hospital

(RADIOLOGICAL TRIAGE TEAM, MEDICAL TEAM, AMBULANCE TEAM)

1. If victim transport is needed before decontamination can be completed, enter the contaminated (Red) zone at the scene of the accident wearing available protective clothing (always wear respiratory protection and double gloves). Liaise with TIC, or other emergency services already at the incident, to ensure that hazards have been evaluated before proceeding into the Red Zone. This must include consideration of conventional hazards i.e. fire, smoke, chemicals etc. as well as radiological hazards.
2. Use a personal alarming dosemeter if a significant gamma source is involved, unless well defined "safe" routes have been identified.
3. Do not eat, drink or smoke while in the Red Zone.
4. Prepare the backboard or other device that will be used to remove the patient from the Red Zone by spreading a first blanket (or other protective barrier, sheet, etc.) and then a second blanket or other barrier on top of the first blanket.
5. Place the backboard or other device in the centre of the blanket and roll up the edges of the blankets and fold blankets over the top of the backboard.
6. After receiving confirmation that is acceptable to do so, enter the Red Zone and place the backboard or other device adjacent to the patient and unroll the protective barriers. **Life threatening injuries should be corrected immediately.**
7. Potentially contaminated casualties should not be given food or water (unless urgent oral medication is required which should preferably be preceded by local facial decontamination).
8. Casualties should be advised not to eat, drink, smoke and keep hands away from the mouth, until decontamination procedures are complete.

Information I.1

Essential information must be documented in the medical record of the emergency department to provide the receiving hospital with all the relevant information, and for possible legal purposes.

All local hospitals, and other medical facilities, should be informed about the incident. This is particularly important if there is a possibility that contaminated casualties will self-present.

In events involving radiation sources, the emergency entrance of the hospital may be accessed by different people including: health care personnel, patients, family members, health authorities and media. The ambulance team should ask for any further instructions, since, for example, the entrance for the ambulance with a contaminated patient may not be the usual emergency entrance.

Information I.3

CAUTION

It is important that emergency services personnel are protected from large radiation doses.

Emergency services staff must be aware of the following:

- Turn back guidance [Table E2];
- The operation and alarms of their dosemeter;
- When responding to a known or suspected malicious act involving sealed sources, do not approach, handle or otherwise come in contact with these sources;
- Radiation dose is reduced by avoiding close proximity to areas of high dose rate or highly contaminated areas; and
- Radiation dose is reduced by minimising time in areas of high dose rate or highly contaminated areas.

Emergency services staff must be trained in advance on how to apply this guidance.

9. Remove patient's clothing except if the victim has serious trauma and needs urgent transport to the hospital. Carefully cut the patient's clothing away from the body, if this can be accomplished without causing harm or unacceptable delay. Otherwise, the clothing should be removed as promptly as possible, without compromising life or limb. Cut clothing on the centre of all body extremities and the trunk. Carefully lay cut clothing open, exposing the patient's body. Prevent hypothermia.
10. Load the patient onto the backboard, leaving clothing behind, using standard medical protocols and wrap the inner protective barrier around the patient.
11. Removed clothing, gloves, and outer blanket should remain in the Red Zone within a labelled plastic bag. The removed clothing and gloves should be considered as waste.
12. Hand carry the patient to the Safety Perimeter of the Red Zone. A second team of care providers should have an appropriate transportation device waiting at the Safety Perimeter. This device should also be covered with a protective barrier.
13. At the Safety Perimeter, responders should pass the patient across the control line to waiting emergency care providers. Care providers within the RED zone should not cross the Safety Perimeter until monitored. If additional responders are not available, the treating responders should either self monitor for contamination and/or remove their protective clothing at the Safety Perimeter and provide transportation of the patient to the appropriate medical facility.
14. After transferring the patient to the clean area, the emergency care providers should cover the patient with the protective barrier that was placed over the transport device.
15. Place floor covering on the ambulance. Load patient into the ambulance and transport to hospital, ensuring that all the relevant information travels with the victim [Instruction I.1:3].
16. Emergency care providers inside the ambulance should wear respiratory protection and other appropriate protective clothing, and change gloves as necessary. Open the protective barrier covering the patient only to administer necessary treatment,

Information Chapter I

Measures to prevent the spread of contamination
The purpose of these actions is to protect the staff and prevent cross contamination.

The two-blanket method will minimise the spread of contamination. The outer-blanket will reduce/eliminate inner blanket contact with contaminated surfaces. The inner blanket, when wrapped around the patient will encapsulate any contamination associated with the patient, helping to prevent further spreading of the contamination. Blankets are recommended instead of plastic sheets to avoid heat shock. Most contamination will be reduced by simply removing the patient's clothing, carefully cutting it away from the body. Hypothermia should be avoided during this procedure, particularly if it is conducted on pediatric patients (e.g. use of warming blankets).

Other measures which can be taken to prevent the spread of contamination are:

- Covering the floor of ambulances using rolls of paper or cloth sheets. The floor covering should be taped securely to the floor;
- Make a path from the ambulance entrance to the hospital entrance using rolls of paper or cloth sheets. The floor covering should be taped securely to the floor and be non-slip; and
- Contaminated or potentially contaminated items such as casualties' clothes, dressings, equipment, staff clothing etc. should be bagged and labelled and stored in a secure area.

and handle all items used in the treatment of the patient as potentially contaminated.

17. Assess patients' vital status during transport and intervene appropriately. Check status of intravenous lines started on site.
18. Inform the receiving hospital of any change in the patients' medical status that occurred during transportation and actions taken during the journey (e.g. venopunctures, administration of fluids/medication, sampling).
19. Vehicles used to transport contaminated casualties should not be decontaminated between journeys, but must be monitored and if necessary decontaminated before return to normal service.

Figure 11. Take care to limit the spread of radioactive contamination when transporting the casualties to hospital. Photo: NRPA.

CHAPTER J

Medical management at the hospital

Introduction

This chapter of the handbook is directed at doctors, nurses and other health workers, who are responsible for actions at the first referral level (hospital response) for the diagnosis, treatment and health care management of people affected by events involving the malevolent use of radioactive sources.

It presents up-to-date guidelines for both inpatient and outpatient care. It was developed to be used in hospitals where basic laboratory facilities and essential drugs and medicines are available.

The guidelines presented in this chapter are the result of a harmonised approach across the EU and are consistent with currently existing international guidance. Actions recommended are evidence-based statements systematically developed to assist decisions about appropriate health interventions. In areas where clinical evidence is limited, recommendations are based on expert experience from recent radiation incidents.

This chapter includes the management of acute radiation syndrome, local radiation injuries, radionuclide contamination and combined injuries.

The hospital's disaster plan and the general guidance for responding to conventional emergencies are part of the preparedness of the emergency health system. Standard procedures for stabilisation of clinical conditions, protocols for supportive care, treatment of conventional injuries and management of thermal burns, are out of scope of this Handbook (they are available at hospitals).
(Bushberg and Miller, 2004; Bushberg et al, 2007; Dainiak et al, 2006).

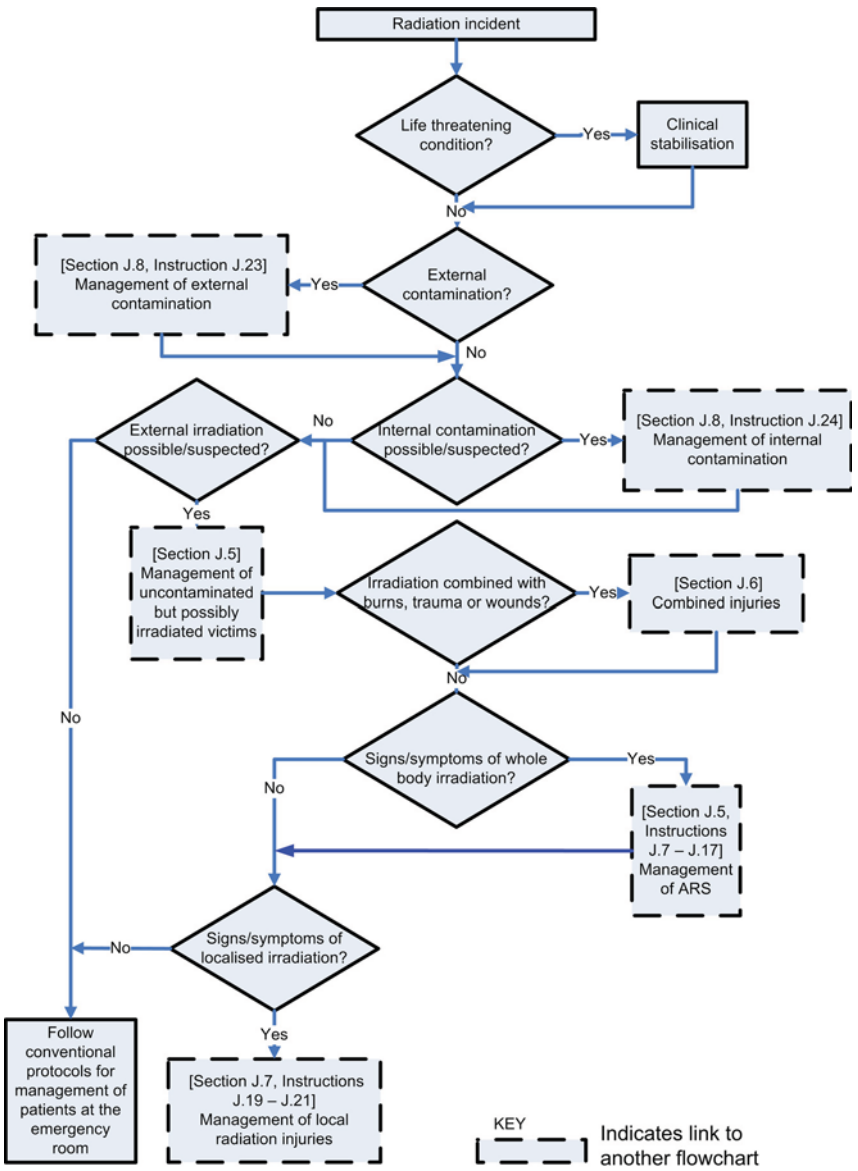


Figure J1. How to go through Chapter J.

1 Receiving notification of the incident

Introduction

This section provides guidance about the minimum information that should be exchanged with the person/s who notify the hospital about the incident. Ideally, a designated member of the hospital staff should be assigned for this task, and should be briefed on her/his role and responsibilities.

J.1 Gathering information from the field

(HOSPITAL EMERGENCY TEAM)

1. Gather information about the event, location, time, size, type of scenario, risk of *radioactive contamination*, nature of the possible contaminant(s) (if known), possible chemical and/or biological hazards and number of patients to be transported.
2. For each patient, request information about identification (e.g. name, age, gender), medical status, conventional injuries, medical problems unconnected with the radiation exposure, actions taken at the scene (e.g. treatment(s), sampling), estimated time of arrival, radioactive contamination suspected or proven, and decontamination procedure conducted in the field.
3. Record the information provided and keep track of updates.
4. Request and record the names of the persons who provided the information and how they can be contacted.
5. Ensure that any further relevant information will be transported with the patients when transferred to the hospital. Request the ambulance team for information about any change in the victim's medical status that occurred during transport and actions taken during transportation (e.g. treatment(s), venopunctures, sampling). Inform them about the location of the ambulance reception area.

Information J.1

Gathering and updating information about the event could be performed by a non-medical staff member.

Collection of relevant information before the arrival of patients is essential for the preparation of the hospital. The person responsible for this task should be informed on the expected role, and the briefing should include basic concepts about radiation protection (e.g. it is possible to safely handle radiation casualties, the difference between exposed vs. contaminated casualties) to ensure that the hospital staff will not hesitate to admit casualties of radiation incidents from fear of irradiation or contamination.

When gathering this information the communication process may involve different individuals, including:

- The Tactical Incident Command (TIC) in the field;
- The ambulance crew;
- Conscious patients arriving by ambulance and those self-presenting; and
- Other persons, e.g. relatives, companions, if the casualty arriving in the ambulance is unconscious.

It is important to know whether biological or chemical agents were present, as these will take precedence over radioactive agents.

It is also important to have an indication of the size of the event (not only about the number of patients who will be transported to the hospital, but also about attendees) to get an idea of the numbers of "worried well" who may be expected to self present at hospitals.

Information J.1:2

Identification of patients, samples and personal belongings should be carefully planned to maintain anonymity and confidentiality while guaranteeing the traceability of the data. Every hospital should have an established system to be performed in an unambiguous way (e.g. unique bar code label). This system should allow for assigning a unique ID to every casualty upon arrival at the hospital and should be able to be scaled up for a sudden influx of patients. In the event of mass casualties, radiation event patients will be transported to, or show up at, various hospitals and may be moved on to specialist clinics. Also, most of the "worried well" will be dealt with in on-scene temporary clearing points or peripheral health care centres, designed to keep them away from the busy hospitals (or they will be managed by their own general practitioners). Since people will have multiple entry points into the health care system, it will not be feasible to impose a universal scheme for identification.

2 Preparing the hospital for patient reception

Introduction

Once the hospital emergency department receives the notification of the incident, it should immediately initiate its emergency plan. It is assumed that such a plan is available at the hospital and the details of its development and execution are out of scope of this Handbook. It is assumed that health care personnel are familiar with conventional emergency management, and that they will be responsible for making decisions regarding initial care of patients, according to standard protocols, until the arrival of external specialists or experts. This section provides specific instructions on how to prepare the hospital for patient reception, that are applicable to radiation emergencies. These instructions should be added to the requirements included in the hospital's disaster plan. The instructions in this section are globally addressed to the "hospital emergency team". This team includes some sub-groups which, in some cases, may be required to deal with more specific tasks e.g. medical doctors, security personnel, administrative personnel, nurses, health physicists and other health workers. These sub-groups will be explicitly mentioned, to help the end-users of the Handbook to identify their own roles during the emergency. The role of the emergency medical manager could be performed by the Director of the Hospital or the Head of the Emergency Department.

J.2 Hospital preparation

(HOSPITAL EMERGENCY TEAM)

Once the hospital is notified that patients will arrive, the following tasks should be undertaken.

(EMERGENCY MEDICAL MANAGER)

1. Activate the hospital disaster plan and notify personnel of the emergency department. Involve personnel with knowledge of radiation protection (health/medical physicist, radiation oncologists, nuclear medicine physicians, radiologists) and alert relevant services such as haematology, surgery, intensive care unit, paediatrics, diagnostic imaging and laboratory services.

Information J.2

Hospital preparation

These instructions should be adapted to local conditions and incorporated into the framework of the hospital's general disaster plan. The HOSPITAL EMERGENCY TEAM should ideally include a coordinator ("manager"); triage officer(s); medical doctors in charge of diagnosis & treatment; nurses and technicians; administrative, maintenance and security personnel. Medical/health physicists and other health care workers may be required. One member of the hospital staff (preferably a medical doctor or senior administrator) should be nominated to deal with the media (public information officer).

While casualties of malevolent acts involving sealed sources (e.g. RED[1]) are not likely to be contaminated, there exists a risk of *radioactive contamination* in scenarios such as RDD[2] or open sources. External contamination will be usually managed outside the hospital. However, conventional casualties (e.g. injuries due to an explosion) may require quick transportation to the hospital before any decontamination procedures. **The HOSPITAL EMERGENCY TEAM should respond bearing in mind that the first priority is to save lives: treatment of life- or limb-threatening conditions should take precedence over decontamination.** In addition to the equipment and supplies required for the management of conventional emergencies, hopital staff should prepare the equipment and supplies likely to be required for the management of a radiation emergency with potentially contaminated patients, to protect the staff and prevent cross-contamination.

Radiation protection equipment (e.g. survey instruments) should be calibrated and used by trained personnel, such as a radiation protection officer or a health physicists. Such equipment may also be available at some departments of the hospital dealing with radiation e.g. radiology, radiation oncology or nuclear medicine. In any case, according to Instruction J.2:3, the relevant competent authority will be alerted about the need for technical support.

(CDC Interim Guidelines, 2003; Dainiak, 2007; Goans and Waselenko, 2005; Gusev et al, 2001; Mettler 2005; Ricks et al, 2002; Turai et al, 2004).

1 RED: radiological exposure devices are devices designed to cause external exposure to ionising radiation.

2 RDD: radiological dispersal device is any device that causes the purposeful dissemination of radioactive material without a nuclear detonation.

2. Identify roles, distribute duties, establish work teams, convene a briefing session to provide the emergency department team with information about the event and define assignments.
3. If it has not already been done, notify the relevant competent authority and alert about the eventual need for participation of specialised teams e.g. radiation protection, radiation emergency medicine, physical dosimetry, biological dosimetry, internal dosimetry, *in vivo* and *in vitro* bioassay. These teams are not routinely part of the staff in most hospitals but they can be available at national, regional or international level to provide on-site or remote assistance.
4. Consider that arriving patients are contaminated until proven otherwise, and prepare the emergency department to prevent the spreading of contamination. Exception: if the absence of radioactive contamination is intrinsically ensured by the scenario conditions and/or by the results of a radiological survey.
5. Allocate an ambulance parking space, and establish the area for ambulance reception, close to the entrance of the treatment area. Identify the path from the ambulance to the emergency room. Whenever possible select areas for reception and treatment of casualties near an outside entrance.

(SECURITY PERSONNEL)

6. Clear the areas for ambulance reception and treatment of causalties from public and patients. Restrict access and establish a system for control of entrances and exits. Re-distribute hospital access and circulation of staff, other patients and public, provide clear signs and erect physical barriers, as necessary.

(HOSPITAL EMERGENCY TEAM)

7. Remove unnecessary equipment and supplies from areas designated for radiation emergency response, cover treatment tables, surfaces and equipment that cannot be removed with waterproof sheets, and prepare personal protective equipment (PPE) and other supplies for the control of sterility and radioactive contamination. Ensure provision of equipment and supplies necessary for the diagnosis and treatment of patients, consider requirements for sample collection and storage and

Information J.2:2

During this briefing session the emergency medical manager should provide the emergency department team with basic concepts on radiation safety i.e. radiation protection principles, management of contaminated patients and objects, use of personal protective equipment and radiation monitors, radioactive waste management, etc. This may be a good opportunity to issue dosemeters. They can be provided by a medical health physicist, radiation protection officer or requested from other departments of the hospital dealing with radiation e.g. diagnostic or interventional radiology, nuclear medicine, radiation oncology.

Information J.2:7

Health care providers should be protected from *radioactive contamination* by using (at least) standard universal precautions. Health care providers should be advised to follow the same procedures as those used to deal with human blood or body fluids when handling contaminated patients and objects.

A checklist of PPE for health care workers should ideally include: face masks, coveralls or waterproof gowns, surgical gloves, waterproof shoe covers or boots and surgical caps (eye protection devices are recommended).

A checklist for decontamination supplies should include: cotton applicators, plastic bags for collection of clothes and personal items, adhesive tapes and labels, towels or disposable wipes, soft nail brushes, tooth brushes, plastic sponges, dressings, gauze, wrapping paper, plastic sheets, general cleansing agents (e.g. saline solution, mild soap, liquid soap, chlorine bleach, shampoo, tooth paste), blankets, and assorted replacement clothing for adult and paediatric patients. Radiation warning signs, rope, assorted pens and notebooks, specimen bottles, emesis basins, and record forms should also be available.

(REAC/TS Guidance, http://orise.orau.gov/reacts/guide/care.htm).

temporary waste disposal, as well as the need for radiation monitors (staff would need to be familiar with their use) [Information J.2:7].

8. Prepare containers for solid and liquid radioactive waste collection, prepare plastic bags of different sizes, labels, radiation tags, worksheets and special forms [Annex 3]. Cover the path from the ambulance to the emergency room, and the floor of the reception and treatment areas, with a non-slippery covering (e.g. wrapping paper) securely taped at the borders. Protect handling surfaces, signal the pathways and rope off.
9. Start preparation for triage, diagnosis and treatment. Verify availability of protocols, procedures, equipment, supplies and worksheets [Annex 3].
10. Identify the equipment to be used for telecommunications during the emergency, check their location, availability and status e.g. telephones, facsimile machine, computers, internet access. Consider also photocopiers, scanners and photographic cameras (for medical photographic records).

(RADIATION PROTECTION OFFICER, HEALTH/MEDICAL PHYSICIST, OTHER QUALIFIED PROFESSIONAL)

11. Verify availability of radiation protection equipment and supplies [Information J.2:7], check status of survey instruments, establish checkpoints for monitoring, e.g. at the ambulance reception area, and at the entrance and exit of the radiation emergency response area.
12. Put on respiratory protection and other PPE [Information J.2:7]. Cover the scrub suit with a water resistant gown. Always wear a cap and boots or shoe covers. Use two pairs of gloves and tape the first pair to the gown or plastic suit. The external pair of gloves should be changed after handling contaminated items or between patients. Dosemeters (if available) should be worn under protective clothing. Personnel dosemeters should be issued to person(s) directly involved in the process of removal and storage of radioactive shrapnel. They can be provided by a medical health physicist, radiation protection officer or by other departments of the hospital dealing with radiation e.g. radiology, radiation oncology or nuclear medicine.

Information J.2:10

It should be borne in mind that there is a potential for communication equipment to become contaminated. This would generally be a minor problem, except for telephones which are necessarily close to the breathing zone during use (risk of internal contamination). Some possible recommendations to minimise these risks are:

- Consider using speakerphones;
- Allow only uncontaminated personnel to use this equipment; and
- Monitor communication equipment regulary.

Information J.2:12

Staff should be instructed to regularly/routinely place their hands over radiation monitors to confirm that their gloves are not becoming contaminated. If this is not possible, outer gloves should be changed frequently.

Staff will need to dispose of gloves to bin(s) identified for radioactive waste – and the bins should be regularly monitored or removed/emptied before they become a significant source of radiation.

If the numbers of personal dosemeters are limited, then consider using a dosemeter to monitor the most active area (e.g. as a sentinel). The results from the sentinel dosemeter could later be used to provide an estimate of individual staff doses on the basis of staff occupancy times.

3 Arrival of patients at the hospital

Introduction

This section provides guidance on the transfer of patients from the ambulance to the emergency room and their admission into the reception and treatment areas. Unlike the toxicity from chemical agents, radiation does not usually cause acute life threatening damage. According to the result of a second trauma triage performed at the hospital, life and limb threatening conditions must always have treatment priority over radiation injuries. Treatment of injured patients should take place according to standard guidelines. As a general criterion, the priority order may be considered as follows:

1. First aid and resuscitation.
2. Clinical stabilisation.
3. Treatment of serious injuries.
4. Management of external contamination.
5. Treatment of internal contamination and minor injuries.

J.3 **Transferring non-contaminated patients with conventional injuries and/or external exposure to the emergency room**
(AMBULANCE TEAM, HOSPITAL EMERGENCY TEAM)
Apply standard procedures for the transport and transfer of patients during conventional emergencies. If no information is available, consider patients to be contaminated until otherwise confirmed, and apply Instruction J.4.

J.4 **Transferring contaminated patients with conventional injuries and/or external exposure to the emergency room**
(AMBULANCE TEAM, HOSPITAL EMERGENCY TEAM)

1. Upon arrival at the hospital, a contamination control zone should be established in and around the ambulance and the ambulance staff should be met by hospital staff wearing respiratory protection and other PPE, as appropriate, at the edge of this zone.
2. The ambulance gurney and the hospital cart should be placed

Information J.3

Persons who received a radiation dose from an external radioactive source were “exposed” to radiation but they are not contaminated (and they do not emit radiation). Thus, standard procedures can be used for transportation/transfer.

Information J.4

A person is contaminated when radioactive material has been deposited on the skin or entered into the body through ingestion, inhalation, wounds or transdermal absorption. Spread of contamination should be prevented in such cases.

These instructions should be adapted to local conditions, resource availability and the magnitude of the incident, bearing in mind the principles of scalability and flexibility.

Ideally, the ambulance and its team will be monitored by personnel trained in the use of survey instruments (radiation protection officers, health physicists, exceptionally other staff members with some knowledge of monitoring such as nuclear medicine personnel, radiology or radiation oncology staff). The number of ambulances required, and the number of times an ambulance will be re-used in the field, will depend on the scenario and magnitude of the incident. The response may need to be scaled-up in a mass casualty event (e.g. use of non-medical transports such as private cars or buses to transport patients).

Similar procedures can be performed for helicopter transport. The landing zone should be considered to be potentially contaminated and the clean team transfer can occur at the border of that zone.

(Bland, 2004; IAEA EPR-Medical, 2005).

side by side at the edge of the zone. Ambulance personnel should stay on one side, hospital staff remain on the other. The patient should then be transferred to the clean gurney, to be admitted for further assessments and treatment.

3. Once the patient has been removed from the ambulance, both the ambulance and crew should not return to regular service (except for life saving transport) until monitored and, if necessary, decontaminated [Information J.4].
4. Submit personal dosemeters to the responsible person or organisation for evaluation of personal doses. Confirm that the ambulance crew did not incorporate radioactive material (e.g. through external monitoring, and initiation of bioassay samples).
5. Ensure the proper disposal of all contaminated clothes, supplies and equipment.

J.5 Receiving patients with conventional injuries and/or external radiation exposure in the emergency room

(HOSPITAL EMERGENCY TEAM)

1. Perform a second triage at the entrance of the area designated for reception of patients in the emergency room [Figure J2]. Second triage should include conventional medical screening of patients, according to their need for treatment (*trauma triage*), to ensure that priority is given to life threatening injuries, before any evaluation concerning radiation injuries (*radiological triage*). Clinical stabilisation of the patients is always the priority. Uncontaminated patients with conventional injuries can be treated in a clean ("cold") area while contaminated patients should be directed to a "dirty" ("hot") area, where decontamination procedures will take place.
2. In the absence of any information (e.g. lack of survey instruments and/or lack of trained personnel), assume that the patients are contaminated until confirmed otherwise. Respiratory protection and other PPE should be worn, as appropriate [Information E.1]. If the absence of radioactive contamination can be confirmed (e.g. by scenario description or monitoring data), revert to the hospital´s standard emergency procedures for patient reception.

Information J.5

Treatment of life threatening conditions is always the first priority. Management of radiation injuries and/or decontamination should neither impede nor delay stabilisation of any patient.

Medical consequences of radiation exposure do not depend on the intentional or accidental nature of the event and decision making about medical strategy will be based on the patient's medical condition and the severity of the injuries. It is important for the treatment to determine whether a conventional injury (trauma, thermal burn) is associated with external radiation exposure and/or radionuclide contamination (external or internal) [Figure J3].

(Smith et al, 2005)

Information J.5:1

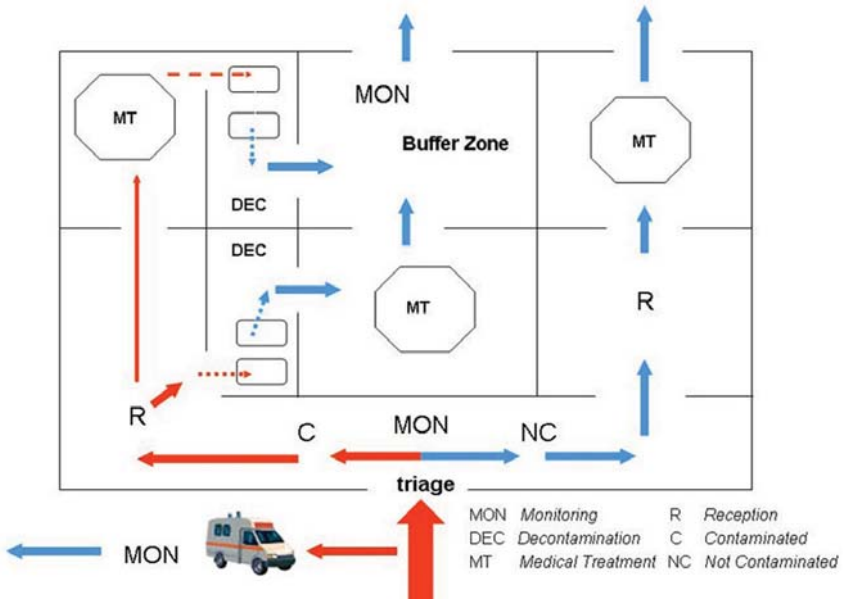


Figure J2. Example of a scheme for preparation of the hospital reception area. The example in the figure should be adapted to the local conditions.

3. Whenever the clinical condition of the patient requires urgent treatment, decontamination procedures should be postponed but staff must wear respiratory protection and other PPE, as appropriate.
4. Depending on the scenario, highly radioactive fragments may be present in wounds and should be removed as soon as possible, following radiation safety procedures. Potentially radioactive metallic fragments should be removed without touching them directly (even if using gloves), using forceps to increase the distance (and thus lowering the exposure of the medical staff). The personnel involved should use PPE. Dose rate must be monitored during this procedure. The fragment(s) must be stored in a heavily shielded lead container and monitored before storage in an appropriate place in the hospital (e.g. radiation therapy department, nuclear medicine department). Person(s) directly involved in removal and storage of radioactive fragments must wear a personnel dosemeter, which can be provided by a radiation protection officer or by other hospital departments which routinely deal with radiation e.g. radiology, radiation oncology or nuclear medicine. Maximum permissible doses for medical staff must be specified [Table E2, Section E.1.1] and compliance ensured by monitoring.
5. If intravenous or intra-arterial access is required in a contaminated patient, swab/clean the area before and, if possible (i.e. available time and/or equipment) monitor the skin and perform the puncture in a clean area, or in the area with a lower degree of contamination.
6. Once treatment has been completed, patients should be passed to a buffer zone and complete monitoring conducted (preferable medical physicist), before their transfer to a free circulation area of the hospital.
7. After initial management in the emergency department, patients may be:
   - Admitted to the hospital (inpatient care) and directed to the appropriate service;
   - Transferred to a higher complexity referral hospital (inpatient care); or
   - Released (outpatient care).

Figure J3. Whenever the clinical condition of the patient requires urgent treatment, decontamination procedures should be postponed but staff must wear respiratory protection and other PPE as appropriate. Photo: WHO.

Information J.5:5

It should always be borne in mind that medical stabilisation takes precedence over decontamination of the skin. Moreover, the amount of radioactivity that might be incorporated through a needle puncture is minimal. Consequently, if any injection is required, it will be sufficient to swab/clean the area, without additional monitoring.

Information J.5:6

Hospital medical physicists will have information about the availability of monitoring equipment and will possess the necessary radiation protection knowledge and skills on the management of radioactive contamination. These members of staff play an essential role in a hospital response to radiation emergencies. Among other tasks, they are involved in:

- Monitoring patients during second radiological triage;
- Supervising and monitoring decontamination efforts;
- Providing support for initial dose estimation;
- Surveying staff involved in the response; and
- Supervising the return of the radiation emergency room to routine use.

8. Patients and staff should be monitored at the last check point before leaving the contamination control area by radiation protection personnel.
9. Consider the appropriate safe, short-term storage and eventual disposal of contaminated materials and wastes (maintenance personnel, nurses, radiation protection personnel).
10. In the short-term, items should be double-bagged and removed under the guidance of radiation protection or health physics staff, to a place where public and staff access is minimised.

4 Performing a second triage at the hospital

Introduction

This section provides guidance on the sequence of steps to sort casualties of radiation emergencies at the hospital. Two kinds of triage are considered:

- Conventional or trauma triage, to sort casualties into groups based on their need for immediate medical treatment as compared to their chance of benefiting from such care; and
- Radiological triage, based on radiological conditions of the casualties in order to direct patients to the most appropriate medical services [Section F.2.2].

Despite the first triage conducted by the field teams, this second triage should be done at the hospital, since the conditions of the casualties will be dynamic and thus may change whilst in transit.

J.6 Second triage

(HOSPITAL EMERGENCY TEAM)

1. Perform a *second trauma triage* based on the medical condition of the patients, which may have improved or worsened.
2. This second trauma triage will identify three levels of priority (**P**):
   - **P1**: need for immediate life-saving medical intervention prior to any decontamination action. These patients may be placed

Figure J4. In the absence of any information, the emergency department staff should assume that the patients are contaminated until confirmed otherwise, and wear respiratory protection and PPE as appropriate.

Figure J5. If contamination is suspected, patient's clothing and shoes should be removed as promptly as possible, without compromising life or limbs.

Photos: WHO.

Information J.6

Conventional or trauma triage is the medical screening of patients according to their need for treatment and the resources available. Although triage systems may differ among countries, the rationale behind the procedures and the basic criteria are quite similar.

Patients are transported to the hospital after they have been classified in the field. An initial or "primary" trauma triage is conducted on-site (pre-hospital level) keeping in mind that the subsequently highest priority should be given to life-threatening conventional injuries. Then, a "primary" radiological triage is conducted in the field by emergency and rescue teams, to identify people who require decontamination and/or emergency admission.

The conditions of the patients are dynamic and they may therefore change after this first triage (e.g. the clinical condition may worsen during transport due to an ongoing haemorrhage or a person who was asymptomatic may start vomiting after field triage). Thus, a second (trauma and radiological) triage should be performed upon the arrival of patients at the hospital.

The second trauma triage is based on medical conditions of the patients and allows them to be classified according to their clinical status, to ensure that priority is given to the management of life threatening conditions. The second radiological triage is based on radiological conditions of the patients and is aimed at directing patients to the most appropriate medical services.

into an isolated area of the hospital, where they can receive urgent treatment, while clean conditions can be maintained elsewhere. Decontamination may be conducted during stabilisation of the patients, if it does not interfere with medical actions. Otherwise, it should be postponed until the end of the treatment.

- **P2**: need for medical intervention, but not immediate. If these patients were not decontaminated at the scene, decontamination may be performed at an appropriate (pre-designated) area in the hospital, by staff wearing respiratory protection and appropriate PPE, prior to further treatment.
- **P3**: less severe injuries, suitable for outpatient health care depending on the results of the second radiological triage. These patients will normally have been decontaminated at the scene before arrival at the hospital. If it is not the case, decontamination may be performed at an appropriate (pre-designed) area in the hospital, by staff wearing respiratory protection and appropriate PPE, before further treatment of minor injuries.

3. Perform a s*econd radiological triage* based on radiological conditions of the casualties in order to direct patients to the most appropriate medical services. In this subsequent triage phase, patients with suspected radiation exposure of unknown severity should be transferred to a hospital medical service capable of identifying radiation induced effects. This includes:
   - Brief case history (based on the information transferred from the field and questioning the victim and/or family members);
   - Basic physical examination (organ system-oriented inventory of health impairments); and
   - Blood sampling: blood cell counts (neutrophils, lymphocytes, platelets, red blood cells, reticulocytes), blood grouping, chromosomal analysis and biochemical profile. Blood samples should be taken at the earliest stage to establish baseline values. Repeat differential blood cell counts every 4-8 hours the first day, every 12 hours the second day and daily thereafter.
4. As a result of this second radiological triage, three categories of patients may be identified (I to III), while bystanders may be considered as score 0 [Table J1].

Information J.6:2

If resources are stretched (e.g. a mass casualty event), it would be appropriate to encourage P3 patients to go home to self-decontaminate [Section G.3] and then return and present themselves as outpatients. Those patients may then be referred to a peripheral health care centre to avoid overwhelming hospitals.

Information J.6:3

The second radiological triage will consider the kinetics and severity of signs and symptoms attributable to radiation exposure (e.g. nausea, vomiting, diarrhea, erythema). Some individuals do not exhibit clinical signs/symptoms, even after being exposed to radiation doses which are known to induce acute radiation syndrome (Dainiak, 2007), and they might not be identified initially as irradiated people. In addition to the evaluation of clinical parameters, the second radiological triage should always include the evaluation of hematological parameters, i.e. sequential complete blood counts (CBC) with white blood cell (WBC) differential.

Information J.6:4

Table J1. Radiological triage categories.

Score	Condition
0	Bystanders who, most probably, were not exposed to radiation
I	Patients that can be followed on an outpatient basis or by a day care hospital structure
II	Patients needing maximum medical effort to be rescued
III	Patients predicted to develop multiple organ failure (MOF), beyond any curative measures

5 Management of uncontaminated but possibly irradiated casualties

Introduction

This section provides guidance on the evaluation and treatment of individuals who have been exposed to radiation (or are suspected of having been exposed) but are neither contaminated with radioactive material nor suffering conventional physical injuries. Depending on the characteristics of the exposure (e.g. dose, dose distribution, radiation quality) and of the patient (age, pre-existing pathologies), some of these individuals may develop a clinical condition named Acute Radiation Syndrome (ARS).

ARS is a set of characteristic signs and symptoms observed after total or large volume partial body exposure to radiation. Most often ARS results from exposure to an acute external penetrating irradiation. However, it could develop after protracted irradiation and also as a consequence of high dose internal exposure (e.g. ingestion or inhalation of a radionuclide).

Before making therapeutic decisions it is necessary to confirm the diagnosis of ARS and assess the prognosis in the shortest time possible.

The objective of the initial assessment of the health status of an ARS patient is to:

1. Assess quickly whether exposure to ionising radiation has occurred.
2. Produce a first tentative diagnosis and assess the severity of damage.
3. Decide whether or not hospitalisation is required (inpatient or outpatient?).
4. If the patient is admitted (inpatient), decide what type of health care facility and sub-specialty consultation will be necessary to ensure provision of appropriate health interventions.
5. Evaluate patient's prognosis and the initial therapeutic approach.

J.7 Diagnostic strategies for ARS

(HOSPITAL EMERGENCY TEAM)

1. Obtain a detailed case history (based on the information transferred from the scene and from questioning the patient and/or family/companions).
2. Collect information on the accident and on the patient's conditions of exposure (scenario, time, distance, position, shielding, risk of contamination).
3. Record current symptoms and signs focused on early radiation reacting organ systems such as haematopoietic system (H), cutaneous system (C), gastrointestinal system (G) and neurovascular system (N). Concentrate on characteristic prodromal ARS signs and symptoms such as nausea, vomiting, diarrhoea, erythema of skin and/or mucosa, headache, abdominal cramps, and unusual fatigue. Note and record time of onset, severity and frequency of any symptoms. Initial shock, unconsciousness, coma, ataxia, and lethargy, are suggestive of a particularly poor prognosis (rule out trauma as a cause of altered neurological function).
4. Look at the first blood cell counts (total and differential white cell counts and absolute lymphocyte counts). A decrease in absolute lymphocyte count or an early granulocytosis are typical prodromal signs observed in ARS patients.
5. Record conventional non-radiation related injuries (e.g. thermal, mechanical). If immediate invasive intervention is necessary, perform surgery as fast as possible (within the first days after the accident).
6. Perform a physical examination of the entire body, including: vital signs, blood pressure, temperature, pulse, and breathing rate. For symptomatic patients, take vital signs every 2 hours. Include ophthalmologic, cardiac, pulmonary, abdominal and neurological examination, and a careful observation of skin and mucous membranes looking for erythema, oedema, blisters, epilation, petechiae, conjunctival haemorrhage. Evaluate the status of salivary glands. Record the patient's weight.
7. Perform blood cell counts, repeat them on a regular basis (every 4-8 hours during the first day, every 12 hours on the second day

Information J.7

The purpose of the diagnostic phase is to obtain all the relevant data to determine severity of the radiation injuries and to establish prognosis. Special emphasis is put on the early reacting organ systems i.e. haematological , gastrointestinal, neurological and cutaneous organ systems. Classical signs and symptoms attributable to radiation exposure should be looked for (e.g. nausea, vomiting, diarrhoea, erythema [Tables J4 - J7]).

Tenderness, oedema and pain of salivary glands (parotid), with an increase in the levels of serum amylase, is an early sign of cephalic exposure. Similarly, slowing of the EEG waves is an indicator of high dose exposure. Conventional trauma combined with ARS, may aggravate the patient's prognosis. If, owing to trauma, immediate invasive intervention is necessary, this should be performed as quickly as possible, prior to, or in parallel with the diagnostic phase. As there is a risk of pancytopenia, surgical measures should be definitive. The time window for performing surgery is restricted to the first 72 hours, due to the possible onset of the pancytopenia, leading to an increased risk of bleeding and infection. Any further surgical intervention should be performed after two months [Section J.6].

Most infections in neutropenic patients come from endogenous microbial flora and they increase the risk of mortality. Sometimes, it is very difficult to detect infections in neutropenic patients (e.g. no fever) and more sophisticated laboratory tests are necessary, such as interleukin-8 and C-reactive protein.

In cases when stem cell transplantation may be required, it is recommended that the search for possible (compatible) stem cell or bone marrow donor(s) among the relatives should be initiated urgently. However, stem cell transplantation is a therapeutic alternative to be considered after 14 to 21 days, in the absence of response to cytokine administration. In severely irradiated patients, growth factors/cytokine therapy should be started as soon as possible. As a result of these evaluations, an organ specific grading is applied and the patient may be categorised according to the type of response required.

and every 24 hours thereafter), record the results in tables and graphics.

8. Perform red cell group typing.
9. Perform qualitative and quantitative assessment of bone marrow smears.
10. Perform laboratory tests including: amylase, electrolyte balance, and functional tests for liver and kidney.
11. Consider other available haematological/immunological tests (e.g. clonogenic assays, lymphocyte subpopulations, and proliferation response tests).
12. Consider feasibility of performing laboratory tests for endocrinology and metabolism.
13. Perform the necessary histocompatibility tests (HLA) in patient/s and potential donors (relatives).
14. Store serum and cells or DNA for further analysis.
15. Obtain an inventory of the endogenous microbial flora (e.g. intestine, skin).
16. Obtain additional information from imaging studies: chest and abdominal radiographs; skin ultrasound using more than 7.5 MHz; CT scans; MRI sequences; thermography; and bone scintigraphy of irradiated territories (as necessary and if available).
17. Obtain one electroencephalogram (EEG) and one electrocardiogram (ECG).
18. Take sample for biological dosimetry [Instruction J.27].
19. If possible, request assistance for dose reconstruction.

J.8 **Primary Scoring of ARS patients (to be used during the first 48 hours)** (HOSPITAL EMERGENCY TEAM)

Table J2 shows a simple method for early patient scoring according to the severity and delay of the main clinical findings (symptoms and signs) and lymphocyte kinetics, during the first two days after exposure.

Information J.8

Acute radiation syndrome (ARS) is not just a single entity but a more complex clinical condition. The classical concept of ARS is defined as a set of signs and symptoms observed after external whole body or large volume partial body exposure. ARS is more often associated with overt exposures, but it may differ if there is a delayed discovery (e.g. covert release) and particularly if the patient's symptoms have been treated before radiation is determined to be the cause. ARS becomes more complex in terms of prolonged, partial, internal and/or organ specific exposure. (Waselenko et al, 2004).

Clinical changes are the result of damage to early reacting organ systems and are mainly manifest within two months after exposure. An early prodromal phase developed during the first week is followed by a clinically silent phase, which is shorter after higher doses.

The score presented in Table J2 is very useful when applied during the first 48 hours after the exposure. The symptoms and signs indicated in the table are reliable only in cases of whole body or large volume partial body exposures, and when the radiation dose is delivered within a few minutes to a few hours. The evaluation of clinical and haematological parameters is generally considered to be the most reliable and available tools to categorise the patients, evaluate the prognosis and decide upon a therapeutic strategy. These parameters are generally applicable to uniform exposures, but they are less applicable and less reliable for non-uniform radiation exposure that might not affect substantial volumes of bone marrow.

The more recent approach to the diagnosis of ARS is the METREPOL SYSTEM, which is focused on an integrative quantification of the radiation-induced damage in some critical organ systems such as neurovascular (N), haemopoietic (H), cutaneous (C) and gastrointestinal (G) to produce a graded code [Instruction J.10]. After very high doses, the prognosis of ARS will rely mainly on the extent of damage to organs other than bone marrow (e.g. lung, gastrointestinal tract, skin), with the risk of multiple organ dysfunction (MOD) and even failure (MOF).

(Weisdorf et al, 2007; Freisecke et al, 2001; Fliedner et al, 2001; Fliedner et al, 2005; Gorin et al, 2006).

(Continued over page)

J.9 Quick strategies to be applied after the initial scoring to deal with great number of casualties

(HOSPITAL EMERGENCY TEAM)

This procedure is intended to be applied during the first 48 hours. It can be particularly useful when there are large numbers of casualties to be managed, while undertaking the necessary actions to properly evaluate them and make decisions about treatment.

1. Life-threatening trauma, wounds and/or burns should be treated first.
2. Remember that an externally IRRADIATED person does not impose any risk to staff and there is no need to use PPE for radiation protection (consider personnel protection for other risks, in accordance with standard procedures in hospital emergency departments).
3. In case of external IRRADIATION associated with RADIONUCLIDE CONTAMINATION, decontamination procedures should be performed immediately following patients stabilisation. In this case use respiratory protection and appropriate PPE [Section J.8].
4. Perform urgent sampling:
   - Blood cell counts every 4-8 hours during the first day[1], and then every 12-24 hours (include platelets and reticulocytes);
   - Red cell group typing;
   - Biodosimetry (see procedure for cytogenetic dosimetry in Instruction J.27);
   - Store serum and cells or DNA for further analysis including HLA typing;
   - Standard biochemistry including amylasemia;
   - In case of neutron exposure: Blood sample (20 ml) to measure ^{24}Na in whole body counting and determination of ^{32}P concentration in hair; and
   - If internal radionuclide contamination is suspected: collect excreta (urine and faeces).

1 The frequency of blood cell counting should be adapted to the number of casualties and existing capabilities

Information J.8 (cont.)

Table J2. Scoring for the first 48 hours[1] (adapted from EBMT, 2007).

	Score I	**Score II**	**Score III**
Delay	**< 12 hours**	**< 5 hours**	**< 30 minutes**
erythema	0	+/-	+ + + < 3rd hour
asthenia	+	+ +	+ + +
nausea	+	+ + +	(-)
vomiting (per day)	1	1-10	>10; intractable
diarrhoea (stools per day)	2-3; bulky	2-9; soft	>10; watery
abdominal pain	minimal	intense	excruciating
headaches	0	+ +	excruciating; ICHT[2]
temperature	< 38 °C	38-40 °C	> 40 °C
blood pressure	normal	temporary decrease	Systolic < 80 mm
loss of consciousness	0	0	temporary / coma
Lymphocytes at 24h	> 1500/µl	< 1500/µl	< 500/µl
Lymphocytes at 48h	> 1500/µl	< 1500/µl	< 100/µl
Strategy	**Outpatient monitoring**	**Hospitalisation for curative treatment[3]**	**Hospitalisation (MOF predicted)**

1 The symptoms and values presented in this table are reliable only in cases where the whole body or large parts of the body have been externally exposed to a high dose absorbed in a short time (minutes to few hours)
2 ICHT: intra-cranial hypertension
3 Depending on the scale of the event, see if some patients on score 2 could be managed as outpatients (e.g. mass casualty event).

Information J.9:4

During exposure to neutrons, the reaction between neutrons and the body sodium gives rise to ^{24}Na, an activated isotope that emits gamma-rays. It is possible to measure these gamma-rays to estimate the specific activity of ^{24}Na (in blood samples or by using whole body counters), which can be used for the retrospective estimation of neutron doses.

The reaction between neutrons and the body phosphorus gives rise to ^{32}P, a neutron activated isotope that can be measured in hair and clothes (other neutron activated products can be also measured in personal belongings).

(Hankins, 1980).

5. Beware of the potential for Multiple Organ Dysfunction (MOD) /Failure (MOF). The severity of the following prodromal clinical features are of major importance to predict MOD/MOF:
   - Extensive and immediate erythema;
   - Temporary loss of consciousness;
   - High fever;
   - Hypotension; and
   - Immediate diarrhoea.
6. Consider and gather information for dose reconstruction:
   - Enquire into the circumstances of the event, type of scenario, source, source-victim geometry, duration of the exposure, shielding, homogeneous/heterogenous irradiation;
   - Collect, label and store personal belongings, clothes, hair, nails, etc.; and
   - If a patient's tooth is removed for any reason, it should be collected, labelled and kept for analysis by electron spin resonance.

   This task can be performed by the health/medical physicist of the hospital (if available), a nurse, auxiliary, other health worker or even administrative personnel (provide instructions). External assistance from the local/national competent authorities (health authority and/or regulatory body) for further processing of the samples should be requested, if necessary.
7. The therapeutic strategy should be selected according to the clinical status of the patient, as shown in Table J3.

   Biodosimetry and dose reconstruction may contribute to evaluating the heterogeneity of the exposure and the feasibility of spontaneous recovery of bone marrow function. Although physical and biological dosimetry are required for later treatment, samples should be taken in the early stages, otherwise data will be lost.

   The dose distribution is more important than the dose itself (e.g. 5 Gy heterogeneous exposure has better prognosis than 4 Gy homogeneous exposure). However, dose estimate (population dose exposure and distribution) is important in terms of

Information J.9:6

The information required to consider further dose reconstruction (i.e. circumstances of the event, type of scenario, source, source-victim geometry, duration of the exposure, shielding, heterogeneity of the exposure, etc.) would have ideally been collected at the scene by the procedures described in section H.5, except in the case of a category P1 patient.

It is important to collect personal belongings, clothes, hair, nails, and even teeth (if removed for any reason) because those materials could be further used for dose reconstruction purposes. Electron spin resonance/ESR (also termed electron paramagnetic resonance/EPR) may be used for retrospective dose assessment in tooth enamel, nails and personal belongings. (Greenstock and Trivedi, 1994; Swartz et al 2006, Swartz et al, 2007; Alexander et al, 2007).

Information J.9:7

Table J3. Selection of the therapeutic strategy according to the clinical status of the patient, based on the scoring for the first 48 hours proposed in Table J2 (EBMT, 2007).

Score	Score I	Score II	Score III
Patient management	Outpatient clinical monitoring	Hospitalisation for curative treatment. Depending on the scale of the event, some patients could be managed as outpatients (e.g. mass casualty event).	Hospitalisation. Prediction of Multi-Organ Failure (MOF)
Supportive care	At least daily blood cell counts for 6 days and weekly for 2 months	Supportive care, blood component therapy as necessary, symptomatic treatment of GI damage, reverse isolation	Palliative/symptomatic treatment. Blood component therapy if considered necessary
Cytokines/ growth factors	no	Early administration of G-CSF for 14-21 days.	Indicated until reassessment of the score. The re-evaluation during the first week will be based on laboratory findings and clinical symptoms
Stem Cell Transplantation	no	Criteria to transplant: severe bone marrow aplasia persisting 14-21 days under cytokines, no residual haematopoiesis, no irreversible organ damage. Type of graft: bone marrow, peripheral HSC, cord blood. Conditioning: fludarabine +/- antilymphocyte globulin. Don't use MTX for GVHD prevention	

G-CSF: Granulocyte-colony stimulating factor
GI: Gastro-Intestinal
MTX: Methotrexate
GVHD: Graft Vs. Host Disease
HSC: Haematopoietic Stem Cells

planning resources required e.g. medical services for the next two weeks and even for the following several months.

J.10 Organ specific grading and Response Categories (RC) to be applied beyond the first 48 hours

(HOSPITAL EMERGENCY TEAM)

The steps for establishing METREPOL organ specific grading, grading code and the corresponding response categories (RC) are the following:

1. Assess signs and symptoms, rating them with a degree of severity between 1 and 4 according to the tables provided for neurovascular (N), haematopoietic (H), cutaneous (C) and gastrointestinal (G) organ systems. Consider as "zero degree" if a given sign or symptom is absent.
2. Take the maximum of any degree found in a given organ system (maximum approach) and attach this number as an index, to the initial representing that organ system.
3. Proceed in this way for the four organ systems (N, H, C and G).
4. The grading code will thus be represented by the four letters (N, H, C and G) with their corresponding indexes.
5. The highest organ specific severity index will determine the response category (RC) at a certain time point (days after exposure).
6. Repeat steps 1-5 at periodic intervals, according to the recommendations provided in Instruction J.11.

On the following pages METREPOL tables for rating signs and symptoms with a degree of severity between 1 and 4 are presented. Four tables are provided for neurovascular (N), haematopoietic (H), cutaneous (C) and gastro-intestinal (G) organ systems.

Information J.10

The manifest illness phase of the ARS becomes clinically evident as a consequence of the impairment of some critical organ systems such as neurovascular (N), haematopoietic (H), cutaneous (C) and gastro-intestinal (G). After exposure to ionising radiation these 4 early reacting organ systems express different signs and symptoms. After very high doses, the prognosis of ARS depend mainly on the extent of damage to organs other than bone marrow (e.g. lung, gastrointestinal tract, skin), with the risk of multiple organ dysfunction (MOD) and even failure (MOF). The METREPOL system of categorisation uses a semiquantitative method for describing signs and symptoms and rating them with a degree of severity between 1 and 4. Zero is used when a given sign or symptom is absent. The combination of clinical characteristics and degree of severity is termed "grading". The highest degree of severity, for a given symptom/sign within one organ, determines the organ specific grading. The combination of the organ specific grading for N, H, C and G is termed "grading code". On the basis of the integration of the elements of the four systems, the highest grading code of a given organ determines the Response Category (RC) [Figure J6, example of RC calculation]. RC reflects the damage to critical organs based on indicators of effect and expressed as a function of time after exposure. Based on this category of response, the patient might be discharged from the emergency department, admitted to a routine care medical/surgical floor, admitted to an intensive care unit of the hospital, or referred to another hospital that has greater relevant specialist capacity.

(Fliedner et al, 2001; Fliedner et al, 2007; Gourmelon et al, 2005).

Table J4. METREPOL: Neurovascular system.

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
		N		
Nausea	Mild	Moderate	Intense	Excruciating
Vomiting	Once/day	2-5 times/day	6-10/day	> 10/day
Anorexia	Able to eat	Decreased intake	Minimal intake	Parenteral nutrition needed
Fatigue	Able to work	Work impaired	Assistance for ADL	Cannot do ADL
Temperature (°C)	< 38	38-40	> 40 for < 24 hrs.	> 40 for > 24 hrs.
Headache	Minimal	Moderate	Intense	Excruciating
Blood pressure (mmHg)	> 100/70	< 100/70	< 90/60	< 80 sistolic
Neurologic deficits[1]	Barely detected	Easily detected	Prominent	Life-threatening LOC
Cognitive deficits[2]	Minor loss	Moderate loss	Major impairment	Complete impairment

1 Reflexes (included corneal), papilledema, seizures, ataxia, other motor and sensory signs
2 Impaired memory, reasoning or judgement
ADL: activities of daily living; LOC: loss of consciousness

Table J5. METREPOL: Haematopoietic system.

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
		H		
Absolute lymphocyte count/µL	≥ 1500	1000-1500	500-1000	< 500
Absolute neutrophil count/µL	≥ 2000	1000-2000	500-1000	< 500 or initial granulocytosis
Platelet count/µL	≥ 100000	50000 - 100000	20000-50000	< 20000
Infection	Local, no antibiotic therapy required	Local, only local antibiotic therapy required	Systemic, oral antibiotic therapy sufficient	Sepsis, intravenous antibiotics necessary
Blood loss	Petechiae; easy bruising; normal Hb	Mild blood loss with < 10 % decrease in Hb	Gross blood loss with 10-20 % decrease in Hb	Spontaneous bleeding or blood loss with > 20 % decrease in Hb

Normal reference values (degree 0):
Absolute lymphocyte count: 1400 - 3500 cells/microliter (µL)
Absolute neutrophil count: 4000 - 9000 cells/microliter (µL)
Platelet count: 140000 - 400000 cells/microliter (µL)

Table J6. METREPOL: Cutaneous system.

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
		C		
Erythema	Minimal and transient	Moderate; isolated patches < 10 cm^2 of body surface (BS)	Marked, isolated patches or confluent; 10-40 % of BS	Severe; isolated patches or confluent; >40% of BS, erythroderma
Sensation/ Itching	Pruritus	Slight and intermittent pain	Moderate and persistent pain	Severe and persistent pain
Swelling/ oedema	Present; asymptomatic	Symptomatic, tension	Secondary dysfunction	Total dysfunction
Blistering	Rare, with sterile fluid	Rare; with haemorrhage	Bullae with sterile fluid	Bullae with haemorrhage
Desquamation	Absent	Patchy dry	Patchy moist	Confluent moist
Ulcer/ Necrosis	Epidermal only	Dermal	Subcutaneous	Muscle/bone involvement
Hair loss	Thining, not striking	Patchy, visible	Complete and most likely reversible	Complete and most likely irreversible
Onycholisis	Absent	Partial	Not defined	Complete

Table J7. METREPOL: Gastro-intestinal system.

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
		G		
Diarrhoea frequency	2-3 stools/day	4-6 stools/day	7-9 stools/ day	≥ 10 stools/day
Stool consistency	Bulky	Loose	Sloppy	Watery
Mucosa loss	Intermittent	Intermittent with large amount	Persistent	Persistent with large amount
GI bleeding	Occult	Intermittent	Persistent	Gross haemorrhage
Abdominal cramps or pain	Minimal	Tolerable	Intense	Excruciating

J.11 Frequency of examination of METREPOL Response Categories (RC)

(HOSPITAL EMERGENCY TEAM)

These instructions provide guidance on the frequency with which the response categories (RC) should be re-evaluated, according to the patient´s condition.

1. If the patient is categorised as *RC1 (mild damage)*:
   (a) Complete system review every 24 hours for 6 days;
   (b) Thereafter once weekly; and
   (c) Final assessment at day 60 post-exposure.

2. If the patient is categorised as *RC2 (moderate damage)*:
   (a) If the patient does not present clinical complications such as bleeding, infections, etc., complete system review every 24 hours for 6 days;
   (b) If the patient has clinical complications, complete system review every 12 hours until stabilisation of symptoms, thereafter once weekly; and
   (c) Final assessment at day 60 post-exposure.

3. If the patient is categorised as *RC3 (severe damage)*:
   (a) If the patient does not present clinical complications such as bleeding, infections, unconsciousness, etc., complete system review every 12 hours for about 6 days. Thereafter, once daily up to day 30. Only if signs of recovery are seen, can the intervals be extended (e.g. examination once weekly);
   (b) If the patient has clinical complications, complete system review every 6 h until stabilisation of symptoms. Then, complete system review every 12 hours for about 6 days. Thereafter, once daily up to day 30. Only if signs of recovery are seen, can the intervals be extended (e.g. examination once weekly); and
   (c) Final assessment at day 60 post-exposure.

4. If the patient is categorised as *RC4 (serious damage)*:
   (a) Complete system review every 6 h for about 3 days (in case of uncertainties or clinical complications, for about 6 days). Thereafter, examine once daily. Only if signs of recovery

Information J.10

Example of METREPOL RC calculation

A patient evaluated two days after the exposure presents:

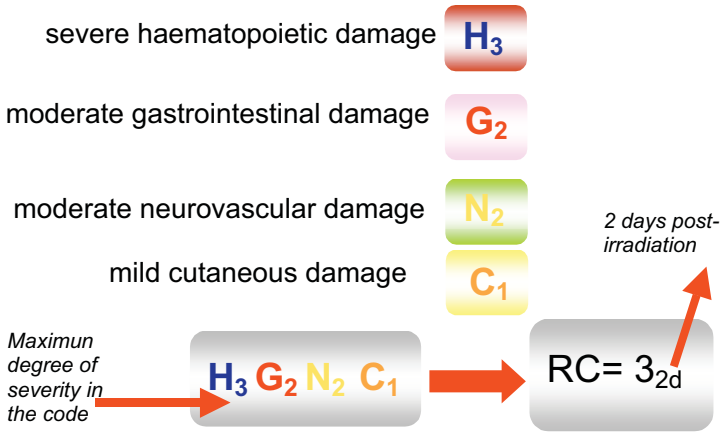


Figure J6. How to calculate the response categories (RC) using METREPOL.

Information J.11

The Response Categories (RC) are intended to be regarded in the daily clinical routine as dynamic values which should be re-evaluated periodically, since the clinical condition of patients is also dynamic and may improve or worsen with time.

can be seen, and no additional complications arise, can the intervals be extended (e.g. examination every 2 or 3 days or once weekly); and

(b) Final assessment at day 60 post-exposure.

J.12 Strategies according to METREPOL Response Categories (RC)

(HOSPITAL EMERGENCY TEAM)

The actions are described in Table J8 below, where the response categories (RC1 to RC4) are correlated with:

- Severity of damage (mild, moderate, severe or serious); and
- Likelihood of autologous recovery.

For each of the four response categories (RC1 to RC4) a strategy is proposed. This strategy includes:

- Institutional levels of care for radiation casualties; and
- RC-dependent therapy.

Table J8. Therapeutic strategy according to the METREPOL response categories.

Response Category (RC)	Severity of damage	Strategy
RC 1	Mild damage Autologous recovery certain	Outpatient care or general medical wards. General support of recovery processes. Usually no specific therapy.
RC 2	Moderate damage Autologous recovery likely	Medical wards with haematological, neurological and dermatological consultation services. Supportive care. Substitutive therapy with blood components.
RC 3	Severe damage Autologous recovery possible	Haematological-oncological institution/service with reverse isolation; intensive care unit; consultations of all medical specialities. Supportive care. Substitutive therapy with blood components. Stimulation therapy (cytokines/growth factors).
RC 4	Serious damage Autologous recovery most unlikely	Specialised hospital with experience in all areas of intensive care medicine, particularly allogeneic stem cell transplantation. Supportive care. Substitutive therapy with blood components. Stimulation therapy (cytokines/growth factors). Stem cell transplantation

Information J.12

Each RC represents a level of damage, which in turn can be associated with a probability of autologous recovery. The requirements for the institution where the patients should be hospitalised are highly dependent on patients' RCs, which in turn require specific therapeutic interventions. The complexity of clinical care required for the patients increases at higher RC.

Accidental radiation exposure is generally heterogeneous. Some under-exposed/protected regions of the bone marrow can provide sufficient residual stem cells to enable endogenous (autologous) haematopoietic recovery, during which time possibly intensive clinical support is needed.

Haematopoietic Stem Cell (HSC) transplantation is not an emergency action. In immune compromised patients, blood components treatment (substitution or replacement) may be followed by Graft Versus Host Disease (GVHD). It is crucial to avoid GVHD in order not to compromise a possible endogenous (autologous) recovery. In order to reduce leucocyte number, all blood products should be irradiated (~25 Gy) prior to administration to a patient with ARS. Only if severe aplasia persists under cytokine treatment for more than 14 days, should HSC transplantation be considered.

(Dainiak et al, 2003; Fliedner et al, 1996; EBMT, 2007).

5.1 Therapeutic principles for ARS patients

(HOSPITAL EMERGENCY TEAM)

J.13 Supportive care for ARS patients

1. Anti-emetic therapy: low effectiveness (e.g. antihistamines) or high effectiveness drugs such as 5-HT3-antagonists (e.g. ondasetron) and dopamine-D2-antagonists (e.g. domperidone). If it is not effective, glucocorticoids combined with neuroleptics may be indicated.
2. Analgesic therapy: follow WHO schemes levels I-III as follows:
   - Level I: non-steroid anti-inflamatory drugs (NSAID) except aspirin;
   - Level II: low effect opiates;
   - Level III: high effect opiates; and
   - If level III is not effective: combine with corticoids and neuroleptics.
3. Brain oedema therapy: corticosteroids (e.g. dexamethasone), mannitol and diuretics.
4. Adapted nutrition: enteral hypercaloric diet, preventing infections, glutamine and sucralfate to protect gut mucosa, parenteral nutrition if needed. Consider electrolyte and fluid replacement according to laboratory data.
5. Prevention of infections: prophylactic antibiotics directed against gram-negative bacilli, using extended-spectrum quinolones or similar agents. Antibiotic therapy specified according to microbiological tests or, if not available, third generation cephalosporin or monotherapy. Suppression of yeast colonisation with fluconazole or alternative agents. Gastrointestinal decontamination with common schemes. Antifungal therapy if febril patients do not respond to antibiotics. Antiviral therapy (to prevent/treat herpes simplex or cytomegalovirus infection). Reverse isolation and protected environment.
6. A standard protocol for the prevention and management of infection in neutropenic patients can be applied e.g.: to start antibiotics if the ARS patient has a neutropenic fever (> 38°C) with an absolute neutrophil count (ANC) of 500/µL or less or if

Information Section J.5.1

In accordance with the response categories (RC), the therapeutic measures should be adapted to the patient's state of health and to the extent of damage to different organs and systems. Individual contraindications and possible side effects should also be taken into account. Therapeutic principles for ARS patients are based on supportive care, substitution (blood component therapy), stimulation (growth factor therapy), stem cell transplantation and surgery (if indicated).

The strategy is based on the principle of allowing spontaneous (autologous) recovery whenever possible. Biodosimetry and dose reconstruction may contribute to indicate the extent of heterogeneity of the exposure and the feasibility of spontaneous recovery of bone marrow function. However, waiting for dosimetry before making decisions on treatment could be detrimental to the patient. The first 24 hours can be considered as an important therapeutic window and clinical dosimetry could be sufficient, especially in highly irradiated casualties.

Supportive care includes the reverse isolation and movement to an environment protected from potential infectious agents because prevention of sepsis is critical in the period of bone marrow aplasia, which depending on the dose and dose distribution, will not occur until several days or even weeks after the exposure.

The criteria for managing ARS patients during the period of bone marrow aplasia are quite similar to those applied for other severely neutropenic patients. Since the patients will not be producing white blood cells, in the case of sepsis, they may not show the typical signs of infection. The most reliable sign, and often the only one, will be a fever (in excess of 38 °C). The presence of any traditional sign or symptom of infection in an ARS patient should be carefully followed, e.g.:

- Respiratory System: cough, bronchial obstruction, crackles, rhonchi, wheezes;
- Urinary system: burning, dysuria, hematuria, cloudy urine, genital secretions;
- Gastro-intestinal: diarrhoea, bloody stools;
- Skin & Mucous Membranes: redness, tenderness, swelling, "fungal" white patches, blisters; and
- Indwelling devices: intra-venous lines and urinary catheters symptomatic for infection.

Platelet substitution prevents bleeding during the bone marrow aplasia period, but risk of overtransfusion should be prevented. The rationale for avoiding surgery during the period of bone marrow aplasia is not to expose an immunosuppressed patient to surgery, to prevent infection and bleeding. To cover wounds at least with a temporary technique will reduce the risk of infections during the aplastic period. (Fliedner et al, 2001; Fliedner, 2006).

their ANC is 1000/µL and is likely to fall below 500/µL in the next 48 hours (e.g. forthcoming nadir) or if there are any signs of infection.

7. Skin treatment: dermoprotector creams in the prodromal phase; later topical or systemic steroids might be considered, hydrocolloid dressings, local infection prophylaxis & treatment; in a later stage pentoxifylline and alpha-tocopherol might need to be applied.
8. Others: mental health interventions, physiotherapy, prevention/ treatment of seizures, hypotension.

J.14 Substitution therapy for ARS patients

1. Blood components should be irradiated (25 Gy) to prevent Graft Versus Host Disease (GVHD).
2. Platelets substitution with threshold as follows:
   - 10 000 /µL if close monitoring is possible, no bleeding, no other complications;
   - 20 000 /µL if close monitoring is not possible, bleeding, no other complications; and
   - 50 000 /µL if additional trauma, surgery, cerebral oedema, transfusions.
3. Erythrocyte substitution: Indications for transfusion should be strict and related to the level of haemoglobin (Hb) according with the hospital criteria. Patients at higher risk of coronary disease or stroke may receive transfusions if Hb < 10 g/dl.

J.15 Stimulation therapy for ARS patients

There are presently several cytokines available for the treatment of radiation induced bone marrow failure:

- Granulocyte Colony-Stimulating Factor (G-CSF), including pegylated forms;
- Granulocyte-Macrophage Colony-Stimulating Factor (GM-CSF);
- Erythropoietin;
- Interleukin 11 (IL-11);
- Thrombopoietin (TPO) and several TPO agonists;
- Keratinocyte Growth Factor (KGF); and
- Stem Cell Factor (SCF).

Additional information concerning ARS

ARS in children

ARS in children may vary depending on age. Children have a number of vulnerabilities that place them at greater risk of harm after radiation exposure. Information about ARS after exposure to ionising radiation in children and the fetus is very limited. It is confined to historic data from the atomic bombings of Hiroshima and Nagasaki, and a few cases of accidental over exposure to orphaned sources or unintended medical exposure (e.g. miscalibration in paediatric radiotherapy). The experience from therapeutic irradiations and paediatric haematology may also be considered, although those situations imply fractionated exposure regimes and/or partial irradiations often combined with chemotherapy.

Paediatric patients should not be split into many categories during an emergency, since the system needs to operate in a cohesive way and allow responders to treat patients in the time available. Dealing with children in subgroups would slow down the response.

For adults, the medical evaluation starts from symptoms (not from doses), but with children and fetuses, biology and prognoses based on the dose reconstruction are relatively more important.

After a delayed discovery, the physician may need to reconstruct the dose 10-20 days after exposure; if a patient received symptomatic treatment, this medical intervention could have modified the clinical picture.

Fetus & pregnant women

Fetal doses can be a significant public health issue and a very emotional subject as one of the options to be considered may be pregnancy termination, depending on gestational age and dose. To provide adequate support for decision making, the professionals involved must rely on dose reconstruction. Individual risk perception and the family context are critical elements in decision making for pregnant women.

The need to identify pregnant women in a population affected by radiation should be evaluated depending on the scale of the event and availability of resources. Although the estimated percentage of total population who are pregnant at a given period varies according to the local CBR[1], for most European countries it could be around 1 % (EUPHIX Public Information System).

1 CBR: crude birth rate is the annual number of live births per 1000 persons

Treatment with cytokines:

1. The use of cytokines is a therapeutic decision that should be made on a case by case basis.
2. The decision will depend on availability of resources and magnitude of the event (number of casualties).
3. There is consensus in the EU that G-CSF (5-10 µg/kg per day) and KGF should be used.
4. SCF could be of interest, but there is some concern about its clinical tolerance. TPO and IL-11 should not be combined.
5. It is desirable to start stimulation therapy as quickly as possible, but blood changes should be observed for at least 24 h (lymphocyte count is an important factor in decision making).
6. The medical staff of the emergency department can wait 24 h for expert advice before taking decisions about stimulation therapy.
7. Once started, the treatment should be continued for 14-21 days (except if, several days after having started the treatment, the results of the biological dosimetry indicate that it should be stopped).

J.16 Stem cell transplantation in ARS patients

1. Haematopoietic Stem Cell (HSC) transplantation may be considered only if it appears that spontaneous haematopoietic recovery will not occur. The absence of residual haematopoiesis should be confirmed.
2. HSC transplantation may be indicated if a severe aplasia persists for more than 14-21 days under cytokine treatment.
3. HSC transplantation is not indicated in patients exhibiting irreversible organ damage.
4. Sources of HSC are: bone marrow, peripheral blood and cord blood.
5. Priorities for donors are as follows:
   - HLA-identical sibling or 7/8 matched;
   - HLA-identical unrelated donor or 9/10 matched; and
   - Cord blood < 4/6 matched.
6. Once the patients for whom HSCT might be indicated have been identified, an oral swab and blood sampling from patients and immediate siblings should be performed for donor searching. In case no family donor is available, high resolution,

Information J.15

The efficacy of cytokines has been demonstrated even when the treatment started around 3 weeks after exposure in people exposed to whole body doses below 5 Gy and/or exhibiting under exposed bone marrow territories. These patients will show a temporary phase of aplasia, but should recover spontaneously. This recovery will take place earlier in case of cytokine administration.
(CDC Neupogen, 2006; Dainiak et al, 2003; Gorin et al, 2006).

Information Section J.5.1

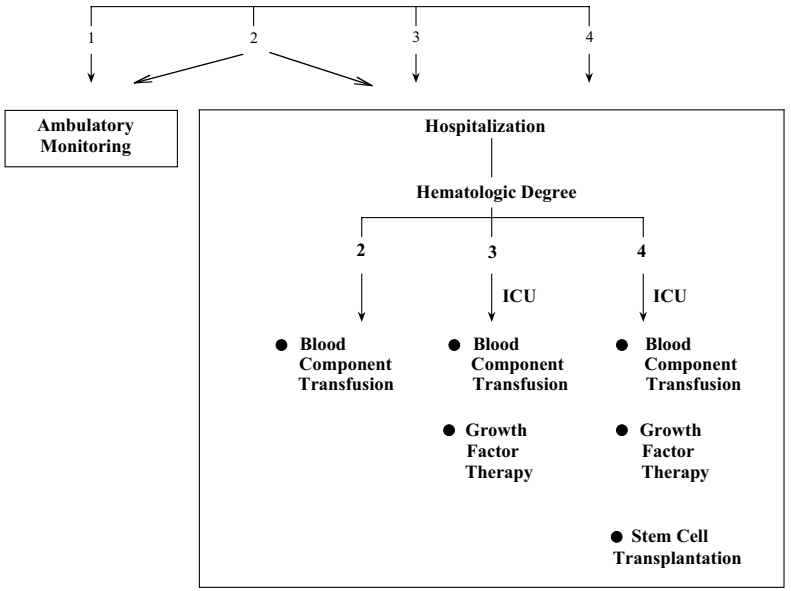


Figure J7. Overall therapeutic approach for ARS patients according to the METREPOL 1-4 Response Categories. Note: ICU -intensive care unit. (Reprinted from Experimental Hematology, 30, Nicholas Dainiak, Hematologic consequences of exposure to ionizing radiation, 513-528, Copyright (2002), with permission from Elsevier).

allele-level HLA typing for HLA-A, HLA-B, HLA-C and HLA-DR loci should be performed on the potential recipient to facilitate the identification of an allogeneic unrelated SC or cord blood donor.

7. Although irradiated casualties may be significantly myelosupressed, they may be incompletely immunosuppressed and they could require additional immunosuppression if a HSCT is envisaged, to prevent graft rejection, particularly if unrelated or partially matched donors are used. Immunosuppresive treatment includes fludarabine (30 mg/m^2 per day for 3 days, alemtuzumab or anti-lymphocyte globulin, accompanied in some cases by alkylators (e.g. cyclophosphamide).
8. Graft Versus Host Disease (GVHD) prophylaxis includes cyclosporine or tacrolimus, in addition to mycophenolate mofetil. Methotrexate should not be used to avoid epithelial toxicity.
9. Doses of cells to be grafted (at least):
   - $2 \cdot 10^6$ CD 34 cells (stem cells)/kg;
   - $2 \cdot 10^8$ bone marrow nucleated cells/kg; and
   - $3 \cdot 10^7$ cord blood nucleated cells/kg.

J.17 Surgery in ARS patients

If surgical interventions are required in a patient with ARS, specific rules should be followed:

1. Surgical interventions should be carried out as early as possible (< 72 hrs) or at a time when risk of bleeding or infection can be controlled (> 2 months after exposure).
2. Non-urgent surgical interventions should be postponed until patient recovery from pancytopenia.
3. Consider wound closure, even with temporary covering, at an early phase.

Information Section J.5

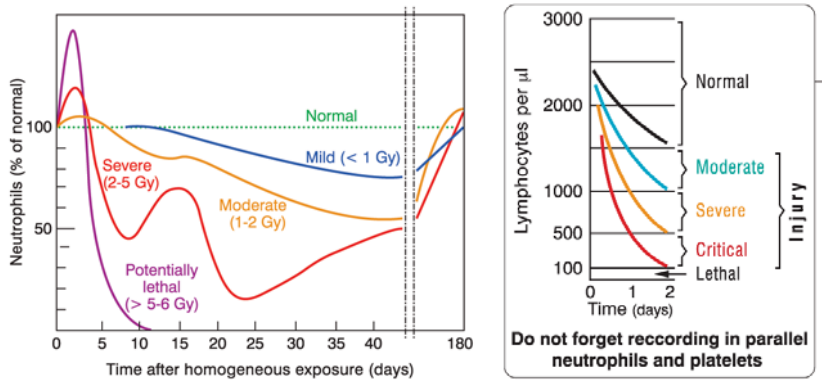


Figure J8. Blood cell depletion curves (reproduced from EBMT, 2007, courtesy of authors).

6 Combined injuries

Introduction

This section provides guidance on the medical management of combined injuries (e.g. medical conditions where the radiation exposure is combined with burns, wounds, trauma or infection).

Since radiation does not cause immediate life-threatening risks, any serious injury will take priority over concerns about irradiation or contamination.

The prognosis for all combined injuries is worse than for radiation injury alone. There is not a simple addition of risks but a synergistic effect. Radiation injury affects the response to trauma and burns and, on the other hand, trauma and burns modify the responses to radiation sickness.

J.18 Criteria for managing combined injuries

(HOSPITAL EMERGENCY TEAM)

1. Evaluate Air-Breathing-Circulation (ABC) and perform standard trauma resuscitation and clinical stabilisation. Maintain ventilation and perfusion and stop hemorrhages. Prevent infection, maintain fluid and electrolyte balance and prevent bleeding. During these procedures, assume the patient is contaminated until confirmed otherwise.
2. Determine if the victim is contaminated with radioactive material. If suitable personnel and/or survey instruments are not available, assume contamination until proven otherwise [Information J.2]. If it has not already been done, remove clothing following procedures described [Instruction G.7] provided it does not cause harm or unacceptable delay. Delay further decontamination until the patient is in a stable condition. Any (potentially contaminated) clothing removed should be bagged, labelled and removed from the area.
3. Staff should wear PPE, particularly respiratory protection, and ideally a personal dosemeter. Alternatively a single dosemeter

Information J.18a

Since radiation does not cause immediate life threatening risks, any serious injury should take priority over concerns about irradiation or contamination. The patient with multiple injuries should be resuscitated and stabilised. Standard preparation for surgery (if necessary) will partly remove the radioactive contamination on the skin.

Combined injuries shift the treatable range of radiation injuries to the lower radiation doses. Experimental data have demonstrated that, when other injuries are accompanied by sublethal irradiation, infections are much more difficult to control and wounds and fractures heal more slowly. Even potentially survivable burns and trauma can be fatal in persons who have also received sublethal doses of radiation.

There is not a simple addition of risks but a synergistic effect. Radiation injury affects the response to trauma and burns (slower healing, loss of weight, loss of granulation tissue, increase risk of infection and haemorrhage, prolonged hospitalisation, increase morbidity and mortality). On the other hand, trauma and burns modify the responses to radiation sickness.

Due to the delay in wound healing and the subsequent neutropenia and thrombocytopenia, most of the life saving, limb saving and reconstructive surgical procedures must be performed within 36-72 hours after exposure. Surgery should then be avoided, if possible, for the next 1-2 months post-exposure.
(Pellmar and Ledney, 2005; Flynn and Goans, 2006).

could be used as a "sentinel" for the area.

4. If metallic fragments are visibly embedded in the body (e.g. tissues, wounds), assume that they are radioactive until proven otherwise and promptly remove them by using long forceps, without touching them directly (even if using gloves). If they are fragments from a radioactive source they could be extremely radioactive. The wounds should then be monitored for gamma activity as soon as possible to determine how staff should proceed.
5. If the fragments are highly radioactive, or if the wound has not been monitored, then the following procedure should be applied:
   - Remove the fragment using two people - one to extract the fragment and the other to assist and quickly remove the excised fragment to a safe location, without direct physical contact;
   - The person removing the fragment (and ideally the assistant as well) must be wearing a dosemeter (capable of providing instantaneous dose rate and accumulated dose) and ideally finger dosemeters (e.g. TLDs);
   - The most active fragment (if known) should be dealt with first and each excised fragment should be safely contained, labelled and removed to an area well away from normal staff operations (until they are dealt with by experienced personnel or confirmed non-radioactive) before the next fragment is removed; and
   - The accumulation (or concentration) of radioactive fragments in staff working areas must be avoided.
6. Staff may need to be changed (or rotated) during this procedure to minimise the individual dose [Tables E1 and E2].
7. Someone should be assigned responsibility for maintaining records of staff exposure, and ensuring that members of staff do not become over exposed.
8. Obtain a medical and exposure history, based on the information transferred from the scene and from questioning the victim and/or family members. Information on mechanisms of trauma and injury, previous pathological conditions, previous medications, and allergies should also be collected.

Information J.18b

If the event includes fire or explosions as well as radiation exposure, it is likely that flame/flash burns will exacerbate with radiation-induced erythema (skin redness). From the very beginning, flame and flash burns are painful, they involve loss of hair and even tissue loss (depending on the depth of the burn). Although the kinetics of radiation burns (or "local radiation injuries" or "cutaneous radiation syndrome") is highly dependent on the local absorbed dose, they usually exhibit an early (primary) erythema but without neither tissue nor hair loss at the beginning (however, they may occur by two weeks after exposure). More detail provided in Section J.7.

Trauma or stress can cause initial lymphocytosis followed by lymphopenia, which may lead to misinterpretations of the blood cell counts used to follow ARS patients. If a trauma or burned patient is in pain, shock or reacting to a medication, vomiting will be a less reliable indicator of ARS. On the other hand, serum amylase is not affected by trauma, unless the parotids are directly involved (e.g. cranial trauma).

9. Conduct an evaluation of the possible external exposure (Acute Radiation Syndrome), take biological samples and follow procedures for ARS described in Section J.5. However, note that absolute lymphocyte counts may be less reliable, due to the physiological response to trauma and/or thermal injury. Hemoconcentration or hemodilution may be seen as a consequence of the injuries, the therapy, or the use of transfusions in patients with hemorrhagia.
10. Treat serious injuries according to standard protocols. A patient with ARS should be subjected to surgery, only if strictly necessary. Such surgery should be completed as soon as possible (i.e. within the first 36 to 72 hours of the radiation exposure). Plan to postpone any additional surgery until hematopoiesis is restored.
11. Decisions on transfer for surgery, burn care or supportive care, are based on the patient's injuries, clinical condition, age, the number of patients, and the availability of resources.
12. Whenever possible, transfers should be performed during the first 72 hours and necessary surgical procedures completed within that period.
13. Following initial stabilisation, radiation exposed trauma or burn patients may be given palliative/compassionate care. The presumption of severe ARS will be based on case history and initial score (early vomiting/diarrhoea, fever, extended erythema, neurological signs/symptoms, early increase in serum amylase, severe lymphopenia, etc.).
14. Patients with ARS and trauma or thermal injury involving more than 10 % of the body surface [Information J.19:8 on the "rule of nines"] should be hospitalised, due to the risk of immunosuppression and pancytopenia. Reverse isolation is recommended, particularly if neutrophil or platelet counts are low, if signs of infection are present, if the victim refers to a pre-existing illness or if the victim belongs to a critical sub-population (e.g. child, pregnant women, elderly).
15. If an ARS patient presents simple fractures, stabilise, perform decontamination (if needed), treat the fracture and then, follow procedures for ARS described in Section J.5. It should be noted that callous formation, is likely to be delayed during the aplasic period.

Figure J9. If the patient presents a fracture, the patient should be stabilised, decontamination should be performed (if needed) and the fracture definitely treated. Then, the procedures for ARS management should be followed. Photos: © Fotosearch.

Additional information to Section J.6

Guidance on minimum standards in emergency and essential surgical care at first referral level health-care facilities is available at http://www.who.int/surgery/publications/imeesc/en/index.html (WHO Integrated Management of Essential and Emergency Surgical Care e-learning tool kit).

7 Local radiation injuries

Introduction

A range of medical terms have been used to describe the clinical condition resulting from the exposure of a localised area of the body to high doses of ionising radiation:

- Localised irradiation;
- Local radiation injuries;
- Radiation burn;
- Radiodermitis; and
- Cutaneous radiation syndrome.

In the context of this chapter, this condition will be referred to as "local radiation injuries" (LRI). General practitioners and emergency physicians should be able to recognise LRI. Unfortunately, in many cases, skin lesions have been misinterpreted by the physicians as insect bites, mechanical trauma, local infections, allergic reactions and even pemphygus. Misdiagnosis unnecessarily delays the appropriate treatment and worsens the prognosis. In scenarios concerning malevolent use of radiation sources, people might not know that they have been exposed to radiation. If whole body dose is not high enough, prodromal symptoms such as nausea, vomiting or diarrhoea may be absent or, if present, such symptoms might be attributed to other causes. The experience from several radiation accidents demonstrates that LRI are quite often the initial reason why casualties require medical advice.

This section provides guidance on the diagnosis and treatment of LRI.

J.19 Identifying the clinical features of local radiation injuries

(HOSPITAL EMERGENCY TEAM)

1. Clinical features of acute skin effects can be related to single radiation exposure as follows :
   - 4-5 Gy: Simple and transitory hair loss;
   - 5-12 Gy : Erythema, followed by hyperpigmentation;
   - 12-15 Gy : Dry epithelitis, with erythema and desquamation;

Information J.19

Cutaneous radiation syndrome (CRS) is an academic concept, proposed to describe an inflammatory reaction of the skin with a particular cytokine profile, observed after radiation exposure. It has been incorporated into texts related to radiation emergency medicine. However, the definition of this term (CRS) is not included in most texts related to conventional emergencies and it is not well understood by general practitioners (GPs). Moreover, following exposure to high doses it is not only the skin which is involved, but also the subcutaneous tissue, and even muscles and bones that are involved (it is more than "cutaneous").

Regarding the use of the term "radiation burn": even though it is more understandable for GPs and emergency physicians, radiation injuries are quite different from classical thermal burns. For the purpose of this handbook, this entity will be termed local radiation injury.

The skin is the largest human organ (between 1.5 and 2 m^2, comprising about one sixth of total body weight). The skin performs multiple roles in human physiology. It helps regulate body temperature and metabolism and protects the body from water loss, friction and impact wounds. It serves as a barrier to the environment and some of its glands have antiinfective properties. Through its specialised pigment cells (melanocytes) it protects from the UV rays of the sun. Human skin consists of three functional layers: epidermis, dermis and hypodermis.

The majority of cells in the epidermis are keratinocytes, which are arranged in stratified layers. Epidermis is a hierarchical tissue. The basal layer of keratinocytes is also called the stratum germinativum, because it is concerned with cell proliferation. Three types of keratinocytes in the basal stratum have been defined by kinetic analysis: stem cells, transient-amplifying cells and committed cells. Stem cells represent around 10 % of the basal cell population and generate daughter cells from mitosis, that are either stem cells themselves or transient-amplifying cells. Transient-amplifying cells represent around 40 % of the basal cell population and replicate with much higher frequency than stem cells, but are capable of only a few population doublings. Transient-amplifying cells produce daughter cells that are committed to terminally differentiate.

These committed cells detach from the basal membrane, differentiate, and ultimately cease to proliferate as they migrate towards the skin surface, where they are sloughed off as dead, cornified cells. This classical hierarchical organisation of the epidermis explains its typical *acute response* following exposure to ionising radiation.

On the other hand, dermis and hypodermis are flexible tissues that mainly develop late effects after radiation exposure. The dermis is composed of water, and, primarily, collagen. Embedded in this layer are systems and structures common to other organs such as: lymphatic and blood vessels, nerve fibers, and muscle cells. Hair follicles, sebaceous glands, and sweat glands are unique to the dermis. (Continued over page)

- 15-25 Gy : Moist epithelitis; and
- 25- 30 Gy : Skin radio-necrosis.

This correlation between skin dose and clinical features has been observed after single high dose rate exposures (i.e. high doses delivered in a very short time). The influence of the dose rate in LRI is not clearly documented and data concerning skin effects after protracted doses (dose delivered over a longer time period) or chronic exposures are very poor. In such cases, similar clinical features would probably be seen after higher doses, due to a longer time available for repair of damage. This is seen with skin reactions observed in patients undergoing fractionated irradiation in radiotherapy, for which the dose thresholds are much higher.

2. Radiation induced late effects on skin include:
   - Skin atrophy;
   - Cutaneous fibrosis;
   - Hyper/hypo pigmentation;
   - Telangiectasia;
   - Hyperkeratosis; and
   - Alterations in nails and hair.
3. Radiation-induced late effects on the skin may involve functional impairment, secondary necrosis and even cancer. One characteristic of local radiation injuries is that, even after wound healing, a secondary necrosis may re-appear several years later.
4. Local radiation injuries (LRI) may evolve in different clinical phases (prodromal phase, illness phase, and late phase) which can extend from hours to years after radiation exposure [Figure J11]. These phases can evolve as an acute, sub-acute or chronic condition. LRI are dynamic, with successive inflammatory waves (pain, oedema, erythema) alternating with periods of no or little clinical symptoms.
5. By using the METREPOL categorisation system, it is possible to define four grades of severity of LRI related to the clinical symptoms and signs [Table J9]:
   - C1: mild damage;

Information J.19 (cont.)

The hypodermis or subcutaneous tissue refers to the fat tissue below the skin. It consists of spongy connective tissue interspersed with adipocytes (fat cells). Vascular endothelium is particularly vulnerable to radiation. Neovascularisation processes as well as *endarteritis obliterans* may be observed after moderate to high dose exposure. Radiation fibrosis is a frequent sequel of radiation overexposure of skin and it is related to a chronic activation of myofibroblasts within these tissues. (Delanian and Lefaix, 2007; Meineke, 2005)

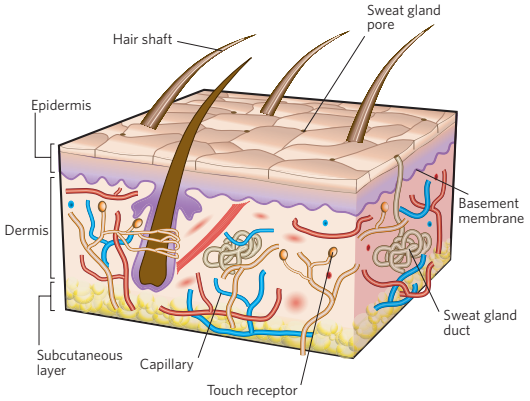


Figure J10. Skin structure. Reprinted by permission from Macmillan Publishers Ltd: Nature (MacNeil, 2007), copyright (2007). www.nature.com/nature.

Information J.19:4

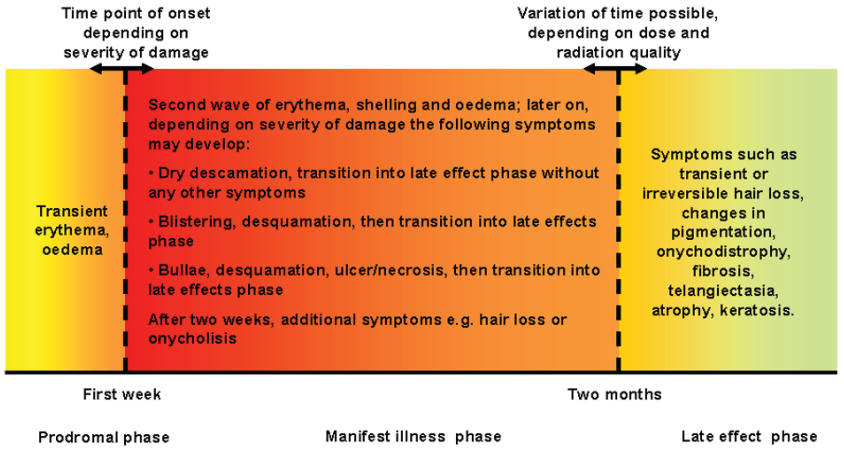


Figure J11. Clinical evolution of LRI.

- C2: moderate damage;
- C3: severe damage; and
- C4: fatal damage

6. Changes in the skin pigmentation may also occur, but this symptom is not included in the METREPOL grading system due to the lack of reference data for depigmentation or hyperpigmentation. Nevertheless, it should be recorded systematically.
7. Although it is only mentioned as a clinical symptom in the METREPOL table for cutaneous system, pain evolution should be considered and recorded as a separate entity, since it is a very good indicator for the prognosis and prediction of necrosis.
8. Information concerning the extent of LRI on surface and in depth, as well as localisation of the lesions should also be recorded. Like in thermal burns, the extent is very important, and the prognosis varies according to the site (e.g. thorax is more critical than buttock) and depth. Standard criteria, similar to those applied to thermal burns, may be used to determine the extent of LRI, e.g. the "rule of nines" [Figure J12].
9. If LRI is suspected, photographs of the affected areas should be obtained on the first day. If signs of radiation injury evolve further, additonal photographs should be obtained daily; otherwise, they should be repeated twice weekly and before/after any surgical procedure (to monitor clinical evolution and therapeutic response, and for legal purposes). These photographs should be labelled (patient ID, date, time) and included in the medical records of the patient.
10. LRI results in skin lesions quite similar to thermal burns. However, thermal burns are different from "radiation burns" in the following respects:
    - Radiological burns are dynamic, their temporal and spatial evolution is unpredictable and even relatively independent of the initial clinical evolution;
    - Patients do not present initial shock;
    - Pain is not immediate in LRI (as it is with thermal burns), but when it later appears it is very severe and resistant to drugs. It is a prognostic symptom which heralds a new wave of

Information J.19:4 (cont.)

Table J9. Grades of severity of LRI.

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
Erythema	Minimal and transient	Moderate; isolated patches < 10 cm^2 of body surface (BS)	Marked, isolated patches or confluent; 10-40 % of BS	Severe; isolated patches or confluent; >40 % of BS, erythroderma
Sensation/ Itching	Pruritus	Slight and intermittent pain	Moderate and persist pain	Severe and persistent pain
Swelling/ oedema	Present; asymptomatic	Symptomatic, tension	Secondary dysfunction	Total dysfunction
Blistering	Rare, with sterile fluid	Rare; with haemorrhage	Bullae with sterile fluid	Bullae with haemorrhage
Desquamation	Absent	Patchy dry	Patchy moist	Confluent moist
Ulcer/Necrosis	Epidermal only	Dermal	Subcutaneous	Muscle/bone involvement
Hair loss	Thining, not striking	Patchy, visible	Complete and most likely reversible	Complete and most likely irreversible
Onycholisis	Absent	Partial	Not defined	Complete

clinical recurrence; and

- Although the kinetics of radiation burns are highly dependent on the local absorbed dose, they usually exhibit an early (primary) erythema without tissue nor hair loss at the beginning (however, they may occur two weeks after exposure), while thermal burns involve early hair and tissue loss (depending on the depth of the burn).

11. Unfortunately, there are no specific clinical features for identifying LRI at the hospital and the presumption of LRI will result from a combination of data:
    - Potentially attributable clinical features (as those previously described);
    - Dynamics and evolution of the lesion(s);
    - Non-explainable burn, unknown cause (no history of previous exposure to chemical, mechanical or thermal injury);
    - Shape of the lesion(s): circular shape suggests exposure to ionising radiation (however anthrax lesions are also circular); and
    - Other people presenting similar signs/symptoms (e.g. family members, neighbours, colleagues).

J.20 Main diagnostic tools in local radiation injuries

(HOSPITAL EMERGENCY TEAM)

1. The diagnosis of LRI during the early phase of an emergency will be mainly based on clinical findings (interrogation and observation). Complementary diagnostic tools may be useful to support the presumption and evaluate the extent and depth of the injury. The results should be combined and interpreted by focusing on the clinical findings.

    - Colour photography is relevant for the documentation of changes as a function of time. Calibration is mandatory to record the dimensions of the lesion(s);
    - Ultrasonography with 7.5 MHz or higher resolution (7.5 - 20 MHz) should be performed daily in the acute phase, and weekly in the manifest illness phase, to determine changes in the thickness and density of the skin. Depending

Information J.19:8

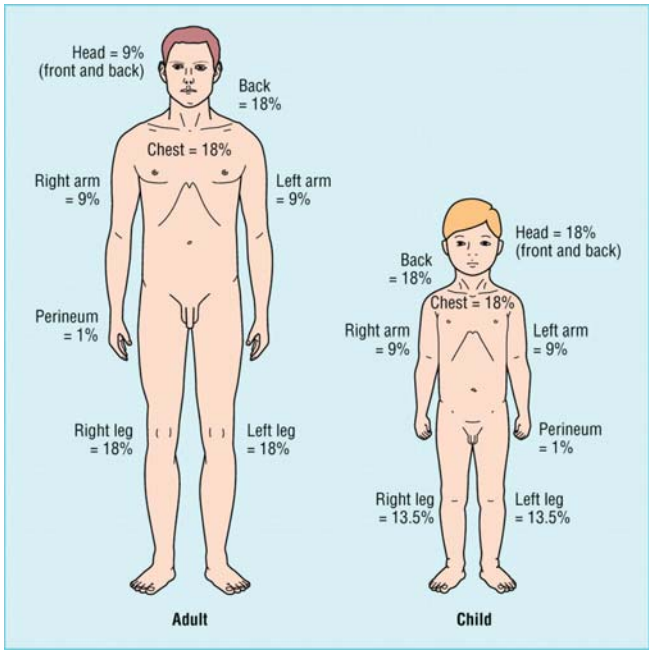


Figure J12. "The rule of nines" (reproduced from British Medical Journal, Hettiaratchy and Papini, 329, 101-103, 2004, with permission from BMJ Publishing group Ltd).

The "rule of nines" may be used to determine the total body surface area (TBSA) that has been burned on an adult. The body surface area that has been burned may be estimated by using multiples of 9 as follows:

- Head = 9 %
- Chest and abdomen = 18 %
- Upper/mid/low back and buttocks = 18 %
- Each arm = 9 %
- Groin = 1 %
- Each leg = 18 %

As an example, if one leg (18 %), the groin (1 %), and the chest and abdomen (18 %) were burned, this would involve 37 % of the body.
The "rule of nines" cannot be used to determine the TBSA of children and infants because their surface area of the head and neck is larger and the limbs are smaller than for adults. The Lund-Browder chart may be used in those cases to compensate for the variation in body shape with age and therefore give a better assessment of burn areas in children.

on the resolution of the equipment, ultrasonography could also provide information about the depth of the lesion, but it cannot be used to plan and guide surgery;

- Thermography can be performed during the first hours and then once weekly, to detect the development of hypertermic or hypotermic skin areas (determination of isothermal lines), in addition to the clinical identification of the erythema. Blisters may cause problems in the interpretation of the results. Thermographic findings may be used as a reference for regular patient follow up;
- Blood flow may be evaluated by capillary microscopy (to evaluate the dermal capillaries) or by doppler ultrasound (to identify damage to larger vessels);
- Magnetic Resonance Imaging (MRI) can be useful in detecting damage in deeper tissues e.g. muscle. Since MRI may demonstrate oedema and inflammatory reactions extending well beyond the lesion, these signs cannot be used alone to guide surgery. However, it was recently demonstrated that MRI is the best tool to provide the anatomical references for dose reconstruction by the Monte Carlo method, which can then guide the surgery; and
- Before ruling out the possibility of LRI, the patient should be followed for at least 4 weeks, to see whether a second wave of erythema appears. If this secondary erythema does not appear within the first 4 weeks, it is unlikely that skin lesions will develop later.

J.21 Medical management of local radiation injuries

(HOSPITAL EMERGENCY TEAM)

1. As a general approach, dermoprotector creams may be used in the prodromal phase; later topical or systemic steroids might be considered, hydrocolloid dressings, local infection prophylaxis and treatment; later still pentoxifylline and alpha-tocopherol might be applied.
2. The treatment of mild (C1) and even moderate (C2) degrees of LRI is relatively simple and undemanding and could be undertaken in most countries. The therapeutic strategy for

Figure J13. Radiation induced epithelitis in hands: it is essential to take photos in colour to record the clinical evolution. Photo: Figure reproduced courtesy of IAEA (IAEA, 2002b).

Information J.20

Main diagnostic tools in local radiation injuries

Colour photography should be performed in addition to a detailed description of the observed sign. It is important to record the dimensions of the lesion(s).

High resolution ultrasonography is a non-invasive method for the evaluation of skin thickness, skin density, ulcer depth and status of the subcutaneous tissues. The depth of radiation fibrosis and ulcers can be determined by 7.5 MHz scanners, while 20 MHz scanners are suitable for investigation of epidermis, dermis and subcutaneous fat tissue up to a depth of 10 mm.

Thermography is a non-invasive method for the quantification of skin temperature and heat loss of the body, which are indirect parameters for skin vascularisation. Techniques such as infrared thermography, microwave thermography and liquid crystal contact thermography are only available in some countries. Thermography is a valuable tool, since necrosis is associated with lower local skin temperature and higher skin temperature is observed in areas with inflammation.

Magnetic Resonance Imaging (MRI) is a non-invasive procedure to evaluate the signal intensity of dermis, subcutaneous fat tissue, muscle and bone, which increases as a result of fluid accumulation (inflammation, oedema, necrosis).

MRI may demonstrate local damage within the first day after exposure and should be used to determe the extent of the lesion, as soon as possible. It is important to take the decision about the indication for surgery, but it may be difficult to discriminate between necrosis and inflammation.
(Peter and Gottlober, 2002).

severe and fatal (C3 and C4) degrees of LRI requires the participation of experts and very often, international assistance.

3. Outpatient treatment is indicated for C1 LRI. This would include anti-inflammatory aqueous lotions/powders, topical anti-inflammatory and antiproliferative non-atrophic glucocorticoids (for suppression of cytokine expression) as well as systemic antihistamines.
4. Treatment of C2 LRI may be on an outpatient basis. Puncture of blisters and non-adherent dressings are usually required. Blisters should not be treated with drying powders. Prevention of infection is important.
5. Hospitalisation is indicated for patients with C3 LRI, with aspiration of blister fluids, debridement of necrotic tissues, topical applications of bacteriostatic agents, anti-inflammatory agents and essential fatty acids, with the use of non-adherent dressings. Systemic treatment will include anti-inflammatory and antiproliferative glucocorticoids and effective analgesia, according to standard protocols [Instruction J.13:2].
6. Hospitalisation in an intensive care unit is indicated for patients with C4 LRI. Instruction J.21:5 may be followed, but these patients will probably also require early surgery.
7. The classical therapeutic approach for severe LRI (C3 and C4) is:
   - Conservative treatment for superficial lesions;
   - Surgery for painful deep ulcerations and necrosis:
     - Ulcerectomy
     - Necrectomy
     - Wound closure by rotation flap
     - Amputation; and
   - In cases of profound and extensive necrosis, the lesion should be excised and the wound bed covered with a good quality, full thickness skin graft.
8. Examples of different options used to cover the lesions after excision are:
   - Rotation flap;
   - Artificial skin graft (INTEGRA®) covered by a silicon sheet.

Information J.21

The follow up of LRI patients will be discussed later [Section K.9:1] . However, some consideration of information that maybe of use in the easrly stages are presented here. LRI patients should be followed for at least 10 years. The risks of deterministic late effects is higher in these patients than ARS patients, and even higher than the risks of stochastic effects. It is common to see people developing lesions resulting from any kind of physical trauma on the irradiated area. Scratches, thermal injury (extremely high or low temperatures), insect bites, or mechanical trauma can easily induce necrosis. This should be prevented by clear recommendations to the patients. Status of vessels is also relevant e.g. people of >80 years old, aging process, hypoxic tissues.

The recommendations to LRI patients during their follow up are more important than in ARS patients. And this also applies to occupational health, a big issue to be considered. LRI can disrupt the occupational life of the patients.
(Schertan et al, 2007).

Figure J14. While conservative treatment may be indicated for superficial lesions, painful deep ulcerations and necrosis require surgical treatment. These photos show the evolution of tissue necrosis after surgical treatment including artificial skin graft. Photos: courtesy of Percy Hospital and IRSN. For artificial skin graft photo, permission also provided by IAEA (IAEA, 2000a).

Colonisation of the artificial skin by patient's cells has been demonstrated. The neoderma covers the artificial skin in a couple of weeks. The silicon is then removed and a classical skin graft is performed on the neoderma;

- Excision on "apparently healthy tissue" followed by a porcine xenograft and later artificial skin graft covered by a silicon sheet. Neoderma develops, allowing the sheet of silicon to be removed and replaced by a meshed autograft; and
- Omentum flap with tunellisation. In one month the omentum is growing and a skin graft can then be performed.

Very often, despite the fact that these diverse approaches are generally successful, necrosis reappears later on and a new autograft(s) will need to be performed.

9. Local administration of human mesenchymal stem cells (MSC) for treating LRI has been used for several casualties of radiation accidents and has demonstrated to be very effective.
   MSC should be injected into the irradiated area after large excision of tissue (e.g. all the volume contained within the 20 Gy isodose). Surgery should be performed as soon as possible (in the first month following exposure), the lesion covered by a skin graft and autologous MSC locally injected ($70\text{-}200 \cdot 10^6$ MSC per injection, in a volume of around 0.5 ml). However, this new promising approach is still under development.
10. A new approach in LRI treatment is dosimetry-based surgery. MRI or CT scan should be used to provide the anatomical information and a numerical voxel phantom should be used for isodose reconstruction by the Monte Carlo method, followed by dosimetry-guided surgery design.
11. Actions that may be considered for the treatment of C3 and C4 LRI, before arrival of specialist, include:
    - Emergency medication could possibly be required during the early phase e.g. steroids;
    - KGF may be useful for the management of local mucositis;
    - Pentoxifillin could be used to improve microcirculation;
    - Prevent/treat infection, and inflammation;
    - Hyperbaric oxygen;

Information J.21:8

The concept of excision on "apparently healthy tissue" for LRI may imply huge exeresis, well beyond the visible injury. The surgeon should be aware of this. Sometimes it is very difficult to convince surgeons, who usually deal with thermal burns, that LRI is a totally different "burn" and that they should remove tissues that will evolve towards necrosis even if they are apparently intact.

Information J.21:9

Human Mesenchymal Stem Cells

Bone marrow- derived mesenchymal stem cells (MSC) are multipotent stem cells that can differentiate *in vivo* or *in vitro* into a variety of cell types such as osteoblasts, myocytes, chondrocytes, adipocytes. Due to these properties, MSC have been used to repair tissue injuries. Experimental studies demonstrated that ionising radiation increases the homing of injected MSC to the injured tissues and to other tissues outside the local irradiation field.

Cellular therapy with *in vitro* expanded MSC was recently used to treat severe LRI. In combination with dosimetry-guided surgery, autologous MSC were locally injected into the lesion. This combined therapy resulted in a favourable clinical evolution with healing progression. This novel approach of regenerative medicine opens new prospects in the medical management of severe LRI. (Lataillade et al 2007).

MSC are currently available in few countries for *in vitro* culture expansion. One advantage of MSC is that they are not HLA specific ("universal donors", options for banking MSC?). Good control of pain is observed soon after MSC administration. However, this technique will not be applicable in a mass casualty event. It is not yet evident whether its use could be scaled up to 15-20 patients. Ongoing research may make it available to be used in larger event.

Information J.21:11

In contrast to C1 and C2 LRI, which are relatively simple to manage, C3 and C4 LRI impose a real challenge. The classical treatment approach may fail and the alternatives are still under development. In selected cases experimental treatments could be used under the supervision of experts. Even in the case of mass casualty events, there should be time to organise international cooperation to ensure expert advice to take care of these patients. The key message already learned in a few of these cases is "to provide supportive care and to wait until the specialists arrive".

- Pain management [Instruction J.13:2];
- Regional sensitive nerve blocking for pain control (different from sympathetic nerve blocking to improve blood flow); and
- Other pharmacological approaches e.g. tracolimus, linoleic acid, calcikrin, prednisolone, and retinoic acid.

8 Radionuclide contamination

Introduction

This section provides guidance for the management of externally contaminated patients at the hospital emergency department. Some general criteria concerning the treatment of internal radionuclide contamination are also described. However, it should be bourne in mind that decorporating agents are not usually available at general hospitals. If it is not explicitly mentioned in the hospital disaster plan, the relevant competent authority coordinating the response in a radiation emergency will provide information on how to obtain the necessary drugs and specialist advice concerning their use.

J.22 **General management of contaminated patients in the hospital**
(HOSPITAL EMERGENCY TEAM)

1. Always give first priority to life support, control of haemorrhage and treatment of trauma.
2. Protect the treatment area and staff with use of isolation, clean transfer techniques, respiratory protection and other appropriate Personal Protective Equipment (PPE).
3. If possible, remove the patient's clothing and place in labelled plastic bags.

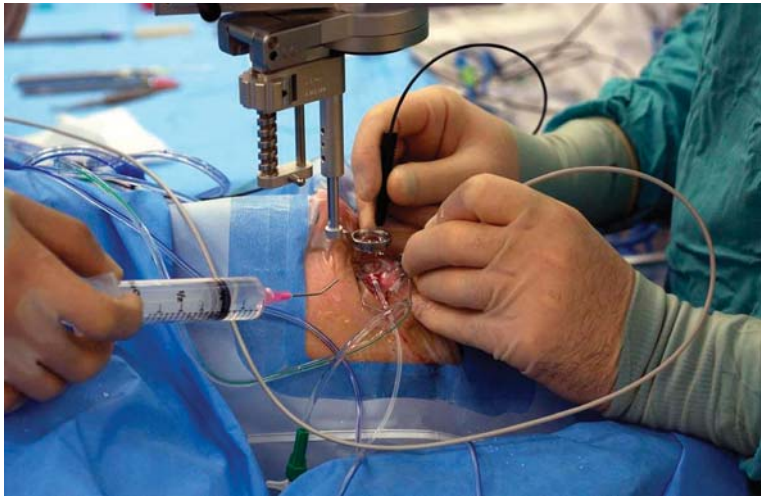


Figure J15. A new approach in local radiation injuries treatment is dosimetry-based surgery. Photo: HPA.

Information J.22

Radioactive contamination is defined as unwanted radioactive material inside the body or on the body (internal or external contamination respectively). In contrast to external irradiation, contaminated patients are continually exposed to radiation until the contamination is removed or eleminated.

Isotope/s identification is particularly important if internal contamination is suspected, to choose the best mechanism for removing the radionuclides from the body, based on their chemical composition. Spread of contamination should be prevented.

The sooner the decontamination procedures start, the lower the dose will be. Contamination levels rarely imply serious hazard to healthcare providers for the time required to perform lifesaving measures and decontamination procedures. One possible exception is where a patient may have embedded fragments from an explosion of a high activity source.
(Smith et al, 2005; Marcus et al, 2005).

4. Assess the patient's medical condition, stabilise and treat as necessary .
5. Survey contamination and document the affected areas along with their levels of contamination.
6. Take samples from affected areas (e.g. eyes, nose, mouth) for analysis and planning of definitive treatment.
7. Conserve specimens from wounds or removed tissues for later analysis. Every sample should be clearly labelled.
8. If possible, identify the isotope/s involved with appropriate techniques [Section H.2:1].
9. Avoid spread of contamination.
10. Document all the procedures and the results of monitoring on appropriate worksheets [Annex 3].

J.23 Management of externally contaminated patients

(HOSPITAL EMERGENCY TEAM)

1. Staff must wear respiratory protection and other PPE as appropriate.
2. Remove patient's clothing and place in labelled plastic bags. Consider washing contamination from breathing zone of casualty and avoid removing clothing over the head. It might be useful to provide the casualty with respiratory protection (after washing nose/mouth) while removing contaminated clothing.
3. Perform monitoring of the patient's skin to delimit contaminated areas and measure and record the level of contamination; the type of radiation detector should be chosen depending on the radioisotopes involved and the type of emission concerned (alpha, beta or gamma emitters).
4. Wash the skin with normal saline solution or a mild detergent. Perform decontamination with the following priorities: breathing zone, site of intravenous access, wounds, mouth, eyes, high level skin areas and low level skin areas (head down body to toes). Be careful not to wash radioactive material into the nose, mouth or wounds.

Information J.23

External contamination is produced when radioactive material, as dust, solid particles, aerosols or liquid, becomes attached to victim's skin or clothes. Early skin decontamination is crucial, as it lowers the risk of internal contamination (particularly important if alpha emitters are present). Moreover, it decreases the risk of radiation skin burns (e.g. skin contamination with beta emitters) and reduces the chance of cross contamination. Most external contamination (around 90 %) is removed with clothing and the remaining skin contamination is usually easily removed by washing. Normal saline solution or a mild detergent are generally sufficient. Mechanical and/or thermal trauma from medical treatment should be avoided; it is better to use flushing and/or friction of cloth, sponge or soft brush, starting with a gentle stream of warm water. Hair and nails can be difficult to decontaminate because particles may become lodged under the nails and become attached to the hair. Protein based shampoos with conditioners should be avoided since they may coat the hair and fix the contaminants. Natural orifices need special attention because absorption of radioactive material is more rapid than through intact skin.

Information J.23:3

It is unlikely that alpha monitors will be readily available in hospitals. Such monitors and expert advice can be obtained from specialist scientific institutes.

Monitoring procedures for alpha emitters should be rigorous (e.g. the monitor must be close to the surface (closer than 1 cm), the area must be monitored more slowly (compared to gamma), surfaces must be dry), to prevent under estimation of alpha activity in a wound or on hair etc. [Annex 6].

5. Document all the procedures and results of monitoring on appropriate forms.
6. Avoid mechanical and/or thermal trauma; do not use harsh cleansers which may compromise skin integrity.
7. Change gloves and survey hands frequently to prevent the spread of contamination to other sites.
8. Perform decontamination by single inward movements or circular motion.
9. After washing, rinse the area with tepid water and gently dry using the same motions. After drying, skin should be re-monitored to determine effectiveness of decontamination. Washing may be repeated (3 times). According to the radionuclide involved, specific solutions may be used instead of non-specific solutions [Information J.23:9].
10. Nail clippers can be used to remove most of the residual contamination under the nails.
11. Wash the hair with a mild shampoo (avoid protein based shampoos with conditioners).
12. For people extensively contaminated, start showering at the head and proceed downwards to the feet, keeping materials out of natural orifices and wounds.
13. Replace shower by bathing for seriously injured patients.
14. Oral cavity: brush teeth with toothpaste, rinse mouth with 3 % citric acid.
15. Pharyngeal region: gargle with 3 % hydrogen peroxide solution.
16. Nose: rinse with tap water or physiological saline.
17. Eyes: rinse by directing stream of sterile water or physiological isotonic saline solution from inner to outer canthus while avoiding contamination of naso-lacrimal gland.
18. Ears: rinse externally with water, rinse auditory canal using ear syringe [Figure J16].

Information J.23:9

Solutions for skin washing may be specific or non-specific

1. *Non-specific solutions:*
   - Common soap and water;
   - Mild detergent solution, low acidity (pH ~5) recommended;
   - Non-soap emollient skin cleansers and water;
   - 3 % hydrogen peroxide solution;
   - 1 % sodium hypochlorite solution (not for facial use);
   - Potassium permanganate 5 % aqueous solution. It should be used carefully only when conventional washing is ineffective (not recommended for face, natural orifices and genital regions). It should be followed by application of reducing agents like sodium hyposulphite 5 % in freshly prepared aqueous solution and then rinsed with water;
   - Mildly abrasive soap or a mixture of powdered detergent and cornmeal mixed with water into a paste can be used for calloused areas; and
   - Antiphlogistic topical ointment for fixed contamination, especially useful for contamination of fingers.
2. *Specific solutions:*
   - Isotonic 1.4 % bicarbonate solution for removing uranium;
   - Lugol solutions for iodine contamination, followed by application of reducing agents like sodium hyposulphite (5 %) in freshly prepared aqueous solution and then rinsed with water;
   - Acetic acid solution (pH 4 to 5) or simply vinegar for phosphorus;
   - Solution of EDTA (10 %) acts as a chelating agent for skin or hair contamination with transuranics, rare earth and transition metals; and
   - Ca-DTPA (1 %) in aqueous acid solution (pH ~4) acts as a chelating agent for washing skin after contamination with transuranics, lanthanides or heavy metals.

(Continued over page)

19. Stop decontamination efforts when:
    - Evidence that skin integrity is beginning to be compromised appears (apply antiphlogistic topical ointment);
    - No significant further decrease of the contamination level is achieved (e.g. no more than 10 %); or
    - Residual contamination level is less than two times background radiation.

J.24 Management of internally contaminated patients

(HOSPITAL EMERGENCY TEAM)

1. Internal contamination must be suspected in patients with external contamination of natural orifices or wounds and in patients admitted with an airway or endo-tracheal tubes.
2. Although it has been suggested that internal contamination may constitute a therapeutic urgency, except for radioiodine there is no clear consensus about empiric treatments for people internally contaminated with radionuclides other than radio-iodine. If the radionuclides involved are not known, specific decorporation cannot be implemented. In the very early phase, treatment decisions are based on accident history rather than careful dose estimate.
3. According to the information provided from the scene (scenario, possible radionuclides involved, route of entry), take relevant samples: urine, faeces, sputum, nasal swabs, vomitus, wound secretions etc.
4. Perform appropriate bioassay, according to the radionuclide involved, to calculate intake, commited effective dose and, where necessary, absorbed dose to organs [Section H.5]. This can be done based on:
    - Whole body measurements;
    - Urinary excretion (sample collected during 24 hours);
    - Faecal excretion[2] (serial samples collected during 72 hours); and
    - Thyroid measurement (for iodine).

2 Not applicable to everybody. The request for faecal samples should be done on a case by case analysis, according to the specialist advice.

Information J.23:9 (cont.)

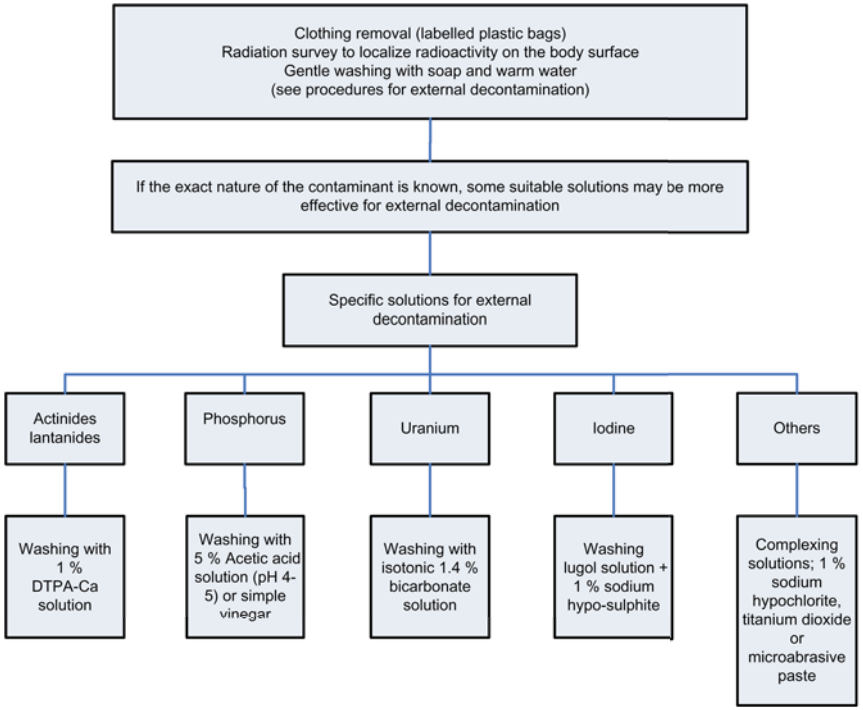


Figure J16. Specific solutions for external decontamination.

Information J.23:19

When to stop external decontamination efforts

The goal of whole body external decontamination is to decrease external contamination to a level of no more than two times the background radiation level [Figure J18].

However, external decontamination procedures should be stopped after 2 decontamination cycles even when the second survey shows that external contamination is higher than 2 times background radiation level, if additional external decontamination efforts do not further reduce contamination levels by more than 10%. In any case, external decontamination efforts should not continue if signs of skin irritation appear. Aggressive and/or vigorous decontamination procedures should be avoided, since they damage skin barrier and increase the risk of internal contamination.
(Continued over page)

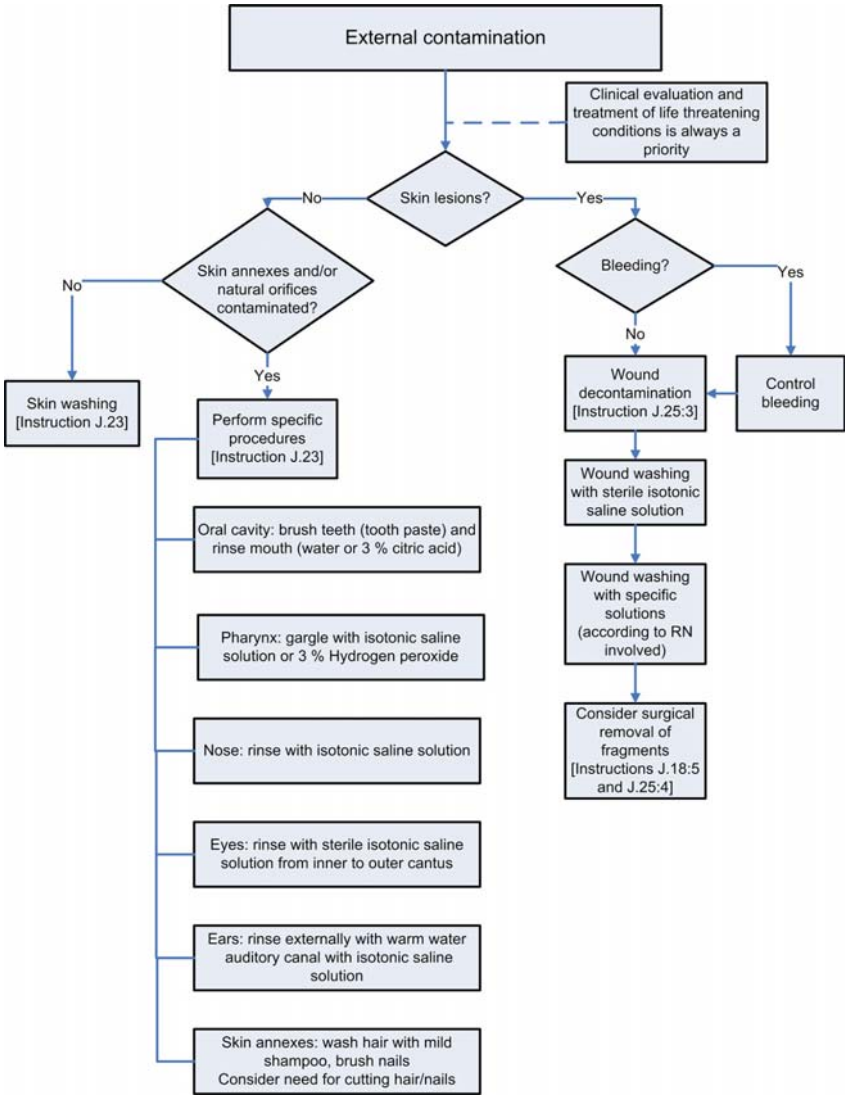


Figure J17. Management of external contamination.

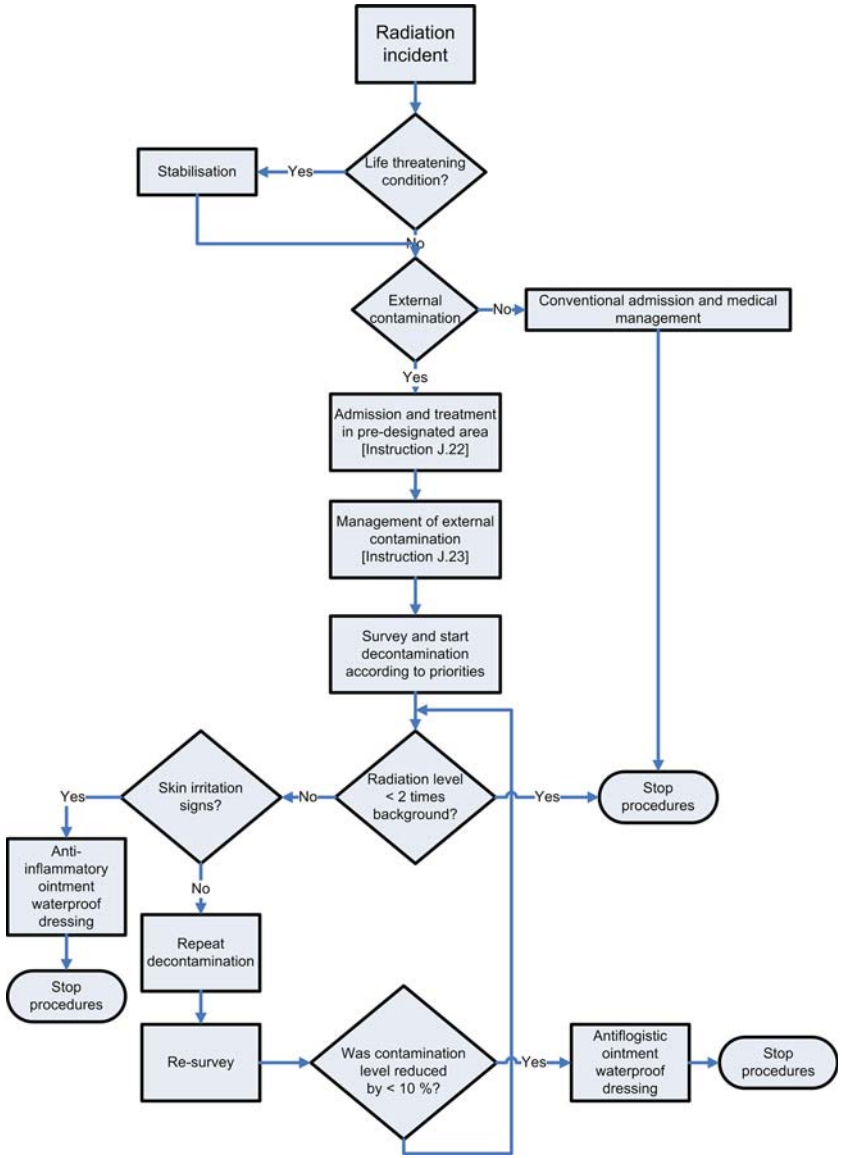


Figure J18. When to stop external decontamination efforts.

5. Radionuclide activity measured in excreta at different times after intake may be used to identify ranges of effective dose with an acceptable level of uncertainty (dose assessment). These data may also be used to follow up the effect of treatment (this approach may be easily applicable to small incidents, but will be less applicable in mass casualty events).
6. Examples of specific agents potentially useful for radionuclide decorporation can be found in Annex 12. In fact, treatment of radionuclide contamination is only indicated in very few cases.
7. Proposed action levels for treatment of radionuclide contamination in adults (intervention criteria) are presented in Table J10 in terms of assessed committed effective dose.
8. Clinical evidence about the use of decorporating and blocking agents in adults is limited. Only a few agents have proven to be effective for treating internal radionuclide contamination. e.g. potassium iodide, DTPA, Prussian Blue. Approval for clinical use by national health authorities and availability for purchase differs among countries.
9. Thyroid blocking using stable iodine can be used to reduce radiation exposure to the thyroid from radioactive iodine. If administered shortly before or at the same time as the exposure to radioactive iodine, it may effectively prevent close to 100 % of radioactive iodine from reaching the thyroid.
   Thyroid blocking is often achieved by oral administration of potassium iodine (KI). Stable iodine can also be administered as potassium iodate (KIO_3).
   Children and pregnant women are at higher risk, since they are more sensitive to radiation exposure. Recommendations on the dosage according to age are presented in Table J11.
   Unfortunately, the effectiveness of iodine thyroid blocking decreases rapidly with time after exposure (e.g. 50 % by 4 hours and very little effect by 12 hours). Because of this limitation, thyroid blocking is not expected to be useful in the case of malevolent use of radioactive sources. This approach could be used if radioiodine is present in the scenario, but only if stable iodine distribution can be performed immediately or within the first few hours. In such situations, the protection of the responders should be considered.

Information J.23:19 (cont.)

It may not be feasible to remove all contamination from the skin. Some radioactive material may be trapped in the outermost layer of the epidermis where it will remain during a normal period of skin cell renewal (i.e. two weeks).

Residual radiation contamination areas should be covered with waterproof dressings to limit the spread of contamination.

If elevated levels of external contamination persist after adequate decontamination efforts, consider:

- Internal contamination;
- Contamination of wounds or body orifices; and
- Retained radioactive fragments (shrapnel).

(REMM, 2008).

Information J.24

Internal contamination may result from inhalation, ingestion, direct absorption through open wounds or intact skin and mucosa. Once the radionuclide crosses cell membranes, it is said to be incorporated. The rate and level of incorporation is related to both the physical and chemical nature of the contaminant. Incorporation can be rapid, occurring in minutes, or it can take days or months. Thus, time may be critical and prevention of uptake is urgent. The following factors determine the extent of the contamination hazard: mode of entry; amount of radionuclides incorporated; energy and type of radiation (nature of the emission); combination of biological and physical half-life (effective half-life); site of deposition (critical organs); chemical and physical properties of the radionuclides.

Information J.24:7

Table J10. Action Levels for treatment of radionuclide contamination.

Assessed committed effective dose	Recommended actions
< 1 mSv	Appropriate for public reassurance that doses pose a minimum risk to health. No treatment
1-20 mSv	More accurate dose assessment is required. Treatment should not be considered.
20-200 mSv	More accurate dose assessment is required. Treatment is subject to medical judgement. Although clinical effects are unlikely to occur, the potential efficacy of extended or protracted treatment should be considered.
> 200 mSv	Treatment should be considered. However, psychological factors and potential efficacy of extended or protracted treatment should be considered.

Adapted from Menetrier et al, 2007b.

10. Ca-DTPA and Zn-DTPA (diethylentriamene pentaacetate) are chelating agents for the treatment of internal contamination with transuranic metals (e.g. plutonium, americium, curium) and other metals. DTPA acts by chelating (binding) the radionuclides in the blood stream and thus speeds up their excretion from the body through urine. The effectiveness of Ca-DTPA in the first 24 hours after internal contamination is 10 times higher than Zn-DTPA. However, after 24 hours, both agents are equally effective. Thus the recommendation is to use:
    - Ca-DTPA for the first 24 hours after internal contamination; and
    - Zn-DTPA (less toxic) thereafter (weeks or months).

    Ca-DTPA or Zn-DTPA should be administered as soon as possible after internal contamination, since effectiveness decreases once these elements are incorporated in bones.
    The recommended dose of DTPA is 1 g in 250 mL normal saline solution, or 5 % dextrose solution, in slow IV administration (control bone marrow and renal function). For pregnant patients, the less toxic Zn-DTPA should be used (if not available, use Ca-DTPA and ensure provision of zinc supplement).
11. Prussian Blue is indicated for decorporation of caesium, rubidium and thallium. It binds radioactive caesium or thallium in the gut and speeds up its excretion from the body through the faeces. Its effectiveness was clearly demonstrated during the Goiânia accident, where it was administrated to a large population (including children and pregnant women). It did not demonstrate adverse effects, except occasional constipation. The recommended dosage is 1-3 g /day (2 to 6 capsules · 0.5 g) for a minimum of 4 weeks or longer, as required. Doses up to 10-12 g/day for significantly contaminated adults may be used.

Information J.24:9

It is important to clearly explain to the population that the iodine is only efficient for internal contamination with radioactive iodine, and that it does not offer protection for any other radionuclide. It also does not protect against external exposure to radiation (need to avoid self administration of stable iodine as a generic “anti-radiation pill”).

Information J.24:9 and 10

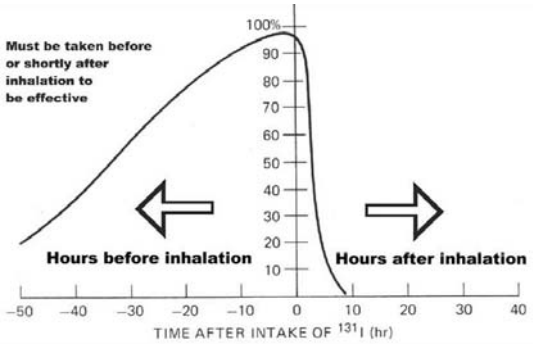


Figure J19.
Effectiveness of iodine thyroid blocking as a function of time after intake (Ilyin, 1972).

Figure J20.
Clinical evidence about decorporating agents is limited to a few agents that have already proven to be effective for treating internal contamination with radionuclides.
Photo: WHO/Olli Häkämies.

Table J11. Recommended single dosage of stable iodine according to age group.

Age group	Mass of iodine (mg)	Mass of KI (mg)	Mass of KIO_3 (mg)
Adults	100	130	170
3-12 years	50	65	85
1 month to 3 years	25	32	42
Neonate (< 1 month)	12.5	16	21

Adapted from IAEA EPR-Medical, 2005.

J.25 Actions to be considered according to the route of entry of the contaminant

(HOSPITAL EMERGENCY TEAM)

According to the radionuclide involved, different therapeutic approaches can be proposed to manage internal contamination. Annex 13 shows examples of some possible strategies. In addition to the systemic treatment, particular actions could be also considered according to the route of entry of the contaminant.

1. *Actions for internal contamination following inhalation of radionuclides:* pulmonary washing (broncho-alveolar lavage) is to be considered only in extreme circumstances after inhalation of very large amounts of insoluble compounds that would be likely to result in major pulmonary problems (fibrosis) if not removed.
2. *Actions for internal contamination following ingestion of radionuclides:* gastric lavage is only effective if done within 1–2 hours after ingestion and should only be used for large single intakes of radioactive material.
3. *Actions for internal contamination following incorporation of radionuclides through wounds:* any wound in an externally contaminated patient should be considered contaminated until proven otherwise. The level of urgency for treatment will be determined by two factors: (a) the uptake rate of the radionuclide from the site, which would determine doses to organs and tissues remote from the wound site; (b) the accumulated dose to tissues in the local area around the wound. The former would be more important for soluble compounds than to insoluble compounds. Medical measures applied to contaminated wounds should assure prompt removal of the radionuclide from the injured area (local treatment) while increasing their elimination from the body (oral or parenteral treatment of internal contamination). While abrasions can be cleaned by washing, lacerations and sometimes punctures, may require local excision of the contaminated tissue, if washing alone is not effective. If the wound is contaminated with soluble compounds, first aid (including washing and possibly tourniquet) given in the first minutes, will be more effective in

Information J.25

In internal contamination following inhalation of radionuclides, the fate of inhaled particles is dependent on their physicochemical characteristics. In general, soluble radionuclides (e.g. tritium, phosphorum, caesium) are absorbed directly into the circulatory system and insoluble radionuclides (e.g. cobalt oxide, plutonium dioxide) are cleared by the lymphatic system or by the mucociliary apparatus above alveolar level. Following inhalation of radionuclides, part of the respiratory secretions reach the pharynx, are swallowed and enter the gastrointestinal system. The contaminant's particle size determines the deposition in the respiratory tract (< 5 μm in diameter may reach the alveolar area; > 10 μm are deposited predominantly in the upper airways).

In internal contamination following ingestion of radionuclides, all swallowed radionuclides enter the digestive tract, but their fate depends on the solubility of the compound. Some radionuclides, in the form of soluble compounds, exhibit high intestinal absorption, (up to 100 %), while for others it can be as low as 0.001 % [Instruction H.61]. Internal contamination of the gastrointestinal tract may result directly from ingestion of contaminated food and water or secondarily from the contamination of the respiratory tract.

Internal contamination may be due to incorporation of radionuclides through wounds. Generally, radionuclides do not cross intact skin, so uptake by this route does not generally occur (exceptions: tritium, iodine, caesium). The radionuclide incorporation rate increases from burns to wounds in the following order:

- Thermal burns;
- Chemical burns;
- Abrasions and excoriations;
- Lacerated wounds;
- Incised cutaneous-muscular wounds; and
- Stab wounds.

(NCRP Report 161, 2008).

(Continued over page)

preventing uptake than excision of tissues, which generally will be performed later. If the wound is contaminated with slowly absorbable radionuclides, surgical excision even after several hours can provide effective removal of wound contaminants. Washing techniques to clean wounds contaminated with non-soluble compounds include the use of chelator compounds (e.g. DTPA, EDTA) which bind the radionuclide into stable, non-dissociable and soluble complexes. Parenteral administration of such compounds to prevent radionuclide incorporation in the body should be done at the earliest possible opportunity.

Chemical burns may easily disrupt the integrity of the epidermis and should be managed in a similar way as contaminated wounds. In general, the rate of radionuclide resorption in thermal burns (with epidermal integrity) is very similar to that for intact skin. When thermal burns are associated with scabs, they will act as an almost impenetrable barrier for resorption. Because of the relatively low rates of radionuclide resorption from thermal burns, medical care should be focused on prophylaxis of local exposure by removing the radionuclides from the injured area (local treatment). However, if the epidermal integrity is altered, e.g. blistering, special attention is required because rupture of blisters will expose underlying layers of epidermis and dermis and consequently increase radionuclide resorption. In these cases, oral or parenteral treatment should be considered for internal contamination.

4. *Actions to be considered to deal with contaminated shrapnel:* if metallic fragments are visibly embedded in the body (e.g. tissues, wounds), assume that they are radioactive until proven otherwise and promptly remove them by using long forceps, without touching them directly (even if using gloves) to increase the distance (and thus lowering the dose rate). The personnel involved should use PPE and a personal dosemeter [Instruction J.18.5].

Information J.25 (cont.)

The contaminating radionuclide may be in the form of soluble or insoluble compounds, which may condition their biokinetics and hence, the choice of the appropriate therapeutic approach. Treatment of internal contamination may include saturation of the critical organ, dilution therapy, isotope displacement or use of chelating agents. The sooner the treatment is started, the more effective it will be. In practice, initial treatment decisions are based on accident history, rather than careful dose estimates. However, health/medical physicists should be involved in dose assessment and clinical toxicologists should advise on potential risks and benefits of decorporation.

Four major phases of internal contamination may be identified:

- Intake and deposit of the radionuclide in the primary compartment (airway, gastrointestinal tract, wounds or intact skin and mucosa);
- Transfer of the radionuclide from the primary compartment through the blood and/or lymphatic vessels;
- Uptake of the radionuclide in organs and tissues; and
- Elimination by excretion organs.

Different therapeutic approaches may be addressed to each of these three phases:

- Prevention of the intake from the entry site;
- Binding of the transferred radionuclide into soluble non-dissociable complexes;
- Decorporation from organs and tissues; and
- Stimulation of radionuclide excretion.

(Berber and Thomas, 1992; CDC DTPA, 2006; CDC KI, 2006; CDC Prussian Blue, 2006; NCRP Report 161, 2008; Wood et al, 2000).

9 Dealing with deceased persons at the hospital

Introduction

While no special procedures are needed to deal with deceased persons after external irradiation, some recommendations should be carried out to deal with human remains containing radioactive materials. This section provides some guidance on this issue.

J.26 **How to deal with deceased persons at the hospital**
(HOSPITAL EMERGENCY TEAM, PATHOLOGY DEPARTMENT)

1. Apply conventional procedures to manage corpses for externally exposed deceased persons, without special precautions.
2. Apply radiation protection measures for managing deceased persons with external and/or internal contamination such as use of PPE for staff, perform basic decontamination if possible, cover the corpse with a plastic sheet or bag, and use appropriate warning tag or label and visible radiation signs.
3. Monitor to determine external dose rate close to the body, and alpha and beta contamination levels on the body.
4. Move the contaminated corpse to the morgue (area should be restricted from workers and public access). If the family of the victim request permission to visit the morgue to mourn, consider the need to move the body to another area, temporarily.
5. Dose rate measurements should be performed as soon as possible upon admission at the morgue (if they have not been done before).
6. Request radiation protection advice before releasing a contaminated corpse. The measurement of contamination in the body or in autopsy samples taken from the body will be a minimum requirement.
7. It is possible that a deceased persons may have radioactive fragments embedded in the corpse (e.g. due to explosions) and

Information J.26

While deceased persons externally irradiated do not represent a risk for health workers, public or other patients, management of contaminated corpses requires radiation protection measures to be considered.

such fragments may be highly radioactive [Instruction J.18:5].

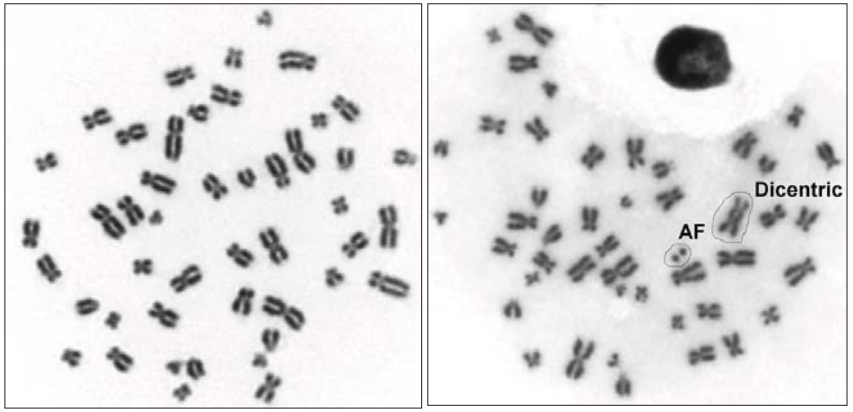
8. Consider issues related to the forensic investigation, particularly if a malevolent act is suspected. If a post mortem examination is essential (e.g. for forensic reasons), considerable planning of radiation protection measures may be required and it is quite possible that the corpse may need to be moved to a more suitable place than is available in most hospital pathology departments.
9. Hospital staff dealing with contaminated corpses (e.g. during the autopsy) should be briefed on basic radiation safety precautions and advised by personnel trained in radiation protection (e.g. radiation protection officer, health physicist, trained personnel from the nuclear medicine department and/or the radiation oncology department).

10 Cytogenetic dosimetry

Introduction

Dose assessment contributes to, but should not be used alone to dictate, medical treatment decisions. As described in previous sections, radiological triage is mainly based on clinical and haematological parameters (e.g. vomiting, blood cell count). A second line of triage is based on cytogenetics, which allows identification of false alarms (i.e. people with symptoms that are not due to radiation exposure: “worried well” people) and verification of high doses and dose distribution that may assist in subsequent treatment.

Biological dosimetry can provide information about dose and the heterogeneity of the exposure, which is crucial for decision making about feasibility of spontaneous bone marrow recovery. It is important to note that it takes at least three days to get results from biological dosimetry. There are some more rapid techniques, but they are generally less accurate.



Normal Metaphase, 46 chromosomes.

Aberrant Metaphase, Dicentric with accompanying acentric fragment (AF).

Figure J21. Biodosimetry is mainly based on cytogenetics, which requires a specialised, calibrated laboratory. Dicentric assay is the gold standard in cytogenetic biological dosimetry. Photos: NRPA.

This section gives advice on the use of current biodosimetric methods that are mainly based on cytogenetics and, in some cases, electron paramagnetic resonance.

Further information on this subject is provided in Section H.3, Section H.4.4 and Annex 9. Detailed guidance on sampling procedure is presented in Annex 11.

J.27 Blood sampling procedure for cytogenetic dosimetry

(HOSPITAL EMERGENCY TEAM)

1. Establish contact with the national biological dosimetry laboratory or the laboratory that performs the biodosimetry service for your country, region or facility (Laboratory preferably meeting the requirements of ISO 19238).
2. Notify the laboratory of the estimated number of subjects for biological dosimetry. In case of a great number of samples, consider in consultation with this laboratory, whether formal or informal networks for biological dosimetry by cytogenetics should be activated. Anticipate type of exposure (if possible).
3. Agree on the number of samples and on the arrangement for the delivery of the samples to the laboratory.
4. Take and transport the blood samples according to procedures described in Annex 11.

Information J.27

Cytogenetic dosimetry assay is not available in most hospitals. It requires a specialised, calibrated laboratory of which there are one or two in some countries, but many countries do not have this resource. There is, nevertheless, within Europe a sufficiently wide geographical spread of laboratories that will respond to a major event and analyse samples. Dose estimates will become available from approximately 72 hours after receipt of the blood specimens. (Alexander et al, 2007; Blakely et al, 2005; Blakely et al, 2009).

Very specialised laboratories (external support at local, national or international level) might be able to measure free radicals generated by ionising radiation in non-aqueous systems, such as teeth, bone, fingernails and hair by a magnetic resonance technique (EPR) (Romanyukha et al, 2005; Trompier et al, 2007).

The hospital emergency team may be requested, by the radiation protection authority or the relevant health authority, to take samples for cytogenetic analysis. The authorities should facilitate the contact between the hospital and the national/foreign specialised laboratories, which can provide information on the type of EPR technique used (i.e. types of samples like teeth, or fingernail or toenail clippings) and how many samples can be sent. The hospital emergency team should follow the advice from the specialised laboratory regarding sampling and the logistics of transportation. (Alexander et al, 2007; Dainiak et al, 2007; Chao, 2007).

CHAPTER K

Public health response

1 Introduction

This chapter provides guidance on public health response and a summary of the main actions to be taken during the initial phase of the emergency, and the expected role of health authorities.

Although public information is addressed in more detail in Chapter D of this Handbook, some considerations of risk communication related to health care workers are presented here.

This chapter provides some basic criteria for establishing peripheral health care centres with the objective of bringing people into the health system while preventing hospitals from being overwhelmed by the "worried well" and by patients seeking primary health care.

The first evidence of radiation exposure resulting from a covert malevolent act may be an outbreak of unusual disease. It is important to raise awareness of this possibility among medical doctors and health authorities, and to help them to identify the types of symptoms that may be attributable to radiation exposure. This is the primary purpose of this chapter.

Finally, guidance for decision making on short-term health surveillance and long-term follow up of casualties is provided.

2 The role of the health authorities during the emergency

The role of the health authorities, during a radiation emergency resulting from a malevolent act, may differ between countries. Health authorities will, in general, be responsible for coordinating public health aspects related to the event (CDC, 2007; IAEA EPR-Medical, 2005; WHO, 2007a), including:

1. To ensure proper interaction with the relevant competent authority which coordinates the response to radiation emergencies at local and national level.
2. To coordinate medical and public health information.
3. To ensure the provision of health services including the establishment of peripheral health care centres.
4. To ensure the provision of safe food and water supplies.
5. To consider water and sanitation and other environmental health issues.
6. To help law enforcement agencies with the criminal investigation of the event.
7. To evaluate the requests for deployment of strategic equipment and supplies (including national or international resources).
8. To convene national experts if necessary.
9. To evaluate the magnitude of the event from a health care perspective, its potential international concern and the need for international notification and/or request for assistance through the appropriate channels.
10. To assist in the establishment of a national registry of exposed individuals.
11. To assist in dose reconstruction and long-term follow up of populations.

3 Risk communication and communication with health care workers

Communication of radiation risks to people involved in emergencies resulting from a malevolent use of radioactive sources, is of paramount importance. The language of radiation protection is not readily understood by non-specialists; radiation dose units, risk nominal probabilities and coefficients for stochastic effects are difficult to understand (Picano, 2004). Patients and general public often personalise risks, even when scientists try to depersonalise it. For instance, a "one-in-a-million" comparison to express cancer risk might be perceived as low by the scientific community, but patients and public may personalise risk and perceive that the "one" could be themselves or a loved one (EPA, 2007).

Risk communication has to address a fundamental dilemma: the risks that kill people and the risks that alarm them are often completely different. There is virtually no correlation between the ranking of hazards according to statistics on expected annual mortality and the ranking of the same hazards by how upsetting they are (Covello and Sandman, 2001).

The people in charge of communicating risk should be skilled in interpersonal communication, be able to convey empathy, and be an effective listener, respectful of people's concerns. They should be knowledgeable about the topic area they are dealing with and be able to answer basic questions about the current as well as possible future risks (EPA, 2007). They should know when to refer a given question to an expert. In terms of public health, ideally this role should be played by known, respected professionals associated with respected institutions or agencies.

Family doctors will be particularly eligible to play this role when communicating risks to individual patients. Radiation doses might be easily be communicated by reporting them as multiples of a chest X ray, which is rather familiar to both patients and health workers and may serve as a "dose unit" to help them to perceive the magnitude of the exposure and the associated risks. Doctors can also communicate risks in a more understandable way through equivalents of risks associated with ordinary life activities such as driving a car (Picano, 2004).

Provision of information to health care workers during radiation emergencies, particularly those associated with malevolent uses of radiation, is essential. In addition to routine briefing/debriefing sessions, further information could be provided through a password protected website, organised by the occupational safety services.

Biological and chemical emergencies pose fewer uncertainties and fears among the staff than radiological hazards. Experience in radiological training courses has demonstrated that staff that initially felt more comfortable in handling biological (80 %) and chemical (60 %) emergencies compared with radiological (40 %), modified their risk perception after being better informed. At the end of the training more than 90 % of the health workers indicated that they would feel more comfortable responding to radiation emergencies than to the others (REAC/TS,

personal communication). Education in such unfamiliar types of emergency is the key to providing the staff with relevant response capabilities and to understanding personal safety issues.

Bearing in mind the infrequency of actual radiological events, on-going professional training, to maintain the level of staff competence, should be built into the emergency preparedness plan: It is useful to integrate the training with that for other hazards, rather than treating radiation in isolation. It is important to ensure that hospitals have an integrated incident management response which is regularly exercised.

Figure K1. Peripheral healthcare centres will conduct the first evaluation and refer patients to the appropriate medical facilities, as necessary. Photo: WHO/Chris Black.

4 Establishing peripheral health care centres

One of the objectives of monitoring is to identify the large groups of people whose exposures are very unlikely to induce a health effect, or who have not been exposed at all. Once identified, these groups can be excluded from further medical treatment or monitoring actions. However, some people could develop later signs or symptoms such as nausea, vomiting, diarrhoea,

skin reddening (erythema) or blistering. Such signs and symptoms, that were not detected during the field triage, might be attributed to radiation exposure and people should be advised to contact the appropriate competent authorities, if they develop them.

Outpatient departments, might become congested with patients seeking primary health care, resulting in long queues of patients, who could be successfully treated at other facilities. Those people should be brought into the health care system in a way that prevents hospitals from becoming overwhelmed, which is particularly important in emergencies with great number of casualties. This can be achieved by establishing peripheral centres with the capacity to provide diagnosis and outpatient care (i.e. primary health care).

Plans to establish peripheral health care services should be made to ensure sufficient staff (technical and non-technical), on a 24 hour operation basis for several days or weeks, depending on the magnitude of the event. These centres will conduct the first evaluation and refer those patients who need further medical assistance to the appropriate healthcare facilities (e.g. general hospital or specialised institution).

To scale up the response, in case of a mass casualty event, health care standards may have to be modified: the aim should be to keep the health care system functioning and to deliver an acceptable quality of care to preserve as many lives as possible.

During the emergency, the competent authorities should provide early warning messages and disseminate their information through press releases, national broadcasting and local radio stations. Written instructions for the early phase of the emergency (e.g. fact sheets in easy-to-understand language), including information about hotline numbers and lists of peripheral health care centres, should be available to the public at strategic distribution points.

After providing assistance, as people are released from these peripheral health care centres, they should be given an information leaflet or fact sheet telling them that the health authorities may need to contact them again for further monitoring or medical evaluation. These fact sheets should contain any relevant health recommendation for the general population and for

critical sub-populations (e.g. children, pregnant women, elderly people, etc.) and list of contact points for news and further information.

Figure K2. Referral hospitals offer advice and support to lower level health facilities. Photo: WHO/Olli Häkämies.

5 Referral hospitals

Referral hospitals offer advice and support to lower level health facilities. Referral hospitals that operate at the regional/provincial level (secondary) will act as referral for the local hospital (primary). Referral hospitals that operate at national/ central level (tertiary) provide more complex and specialised services to patients who have been referred from communities where such services are not available.

Referral hospitals provide support to other health facilities, either in assisting patients or giving remote advice on the management of patients' conditions, and whether and when to refer or discharge the patients. In some countries, referral hospitals can provide managerial and administrative support to other elements of the health system, including managing more complex laboratory services, serving as drug and medical supply depots, managing health information systems, central transport fleets and human resource support.

Medical research is often undertaken at referral hospitals. New technologies are therefore being applied, which may be particularly important when dealing with complex clinical conditions, such as acute radiation syndrome and severe local radiation injuries.

6 Dealing with worried well

During radiation emergencies, health authorities should make provisions for dealing with a large number of people who may self report experiencing symptoms or even as asymptomatic patients. Those people are concerned about possible exposure to radiation, even if it did not occur.

The term "worried well" includes people worried about their health from the potential risks of an accident. In addition to radiological and nuclear emergencies, they have been also described in biological and chemical emergencies, as well as natural disasters.

The "worried well" may develop sub-clinical anxiety and/or chronic somatic preoccupation. Some of their psychosomatic symptoms may mimic those symptoms that can be attributable to radiation exposure, such as nausea and vomiting. Therefore, differential diagnosis is essential and the health care facilities should identify true symptomatic patients, to avoid transferring to hospitals people who do not require medical assistance.

Provision of information is the key for dealing with "worried well". Clear information about the event should be provided through the media, and the public health services where people may ask for assistance or counselling. In the midst of a community crisis, such a radiation emergency, the impact of these messages may exert a strong influence. Sometimes casualties may experience frustration and feelings of helplessness related to local or national governmental authorities. Brief non-sensationalistic press releases, broadcasting, posters and leaflets may be valuable tools to reassure the public, including the "worried well".

In addition to peripheral health care centres, some local institutions such as schools, church, social clubs, cultural centers and non-governmental organisations may serve as focal points for provision of support to worried people (WHO, 2003). Teachers may play a relevant role in providing emotional support for children and parents. In the case of foreign citizens

the information and support provided by their local embassies will be of great value. The formation of stakeholder advisory groups can also be a valuable mechanism for building trust, helping the casualties to feel that their views are important and are taken seriously (Becker, 1997).

7 Outbreak of unusual disease attributable to radiation exposure

After an overt release of radioactive material (e.g. a dirty bomb) the emergency departments of the hospitals will probably be aware of the presence of radioactive material at the scene of the event. This may not be the case if the exposure resulted from a covert release in the context of a malevolent act (e.g. a radioactive source hidden in a public place).

An ongoing outbreak of an unusual disease may be the first indication. The suspicion that such an outbreak could be attributable to radiation exposure may be considered if a large group of people exhibit a characteristic pattern of illness including nausea, vomiting, diarrhoea and/or skin damage (e.g redness, alopecia, unusual “burns”), particularly if it is associated with typical haematological changes (e.g. lymphocytopenia, granulocytopenia). A more systematic surveillance should be implemented to identify the cause of the outbreak, and to confirm or reject the hypothesis of a radiation incident.

If an unusually large number of patients presenting two or more of those signs/symptoms is detected, the health professional/s should inform the appropriate competent authority to start an investigation (health surveillance). Epidemiological intelligence can be used to alert authorities to look for similar cases in their own jurisdiction.

In brief, outbreak management involves several steps:

1. Epidemic detection and alert demands the timely reporting of data through the public health hierarchy – local, regional, provincial, national or international, as appropriate.
2. Rapid epidemiological assessment is essential, at the beginning of an outbreak or epidemic, to define initially the scope of the problem (clinical pattern, initial number and distribution of cases).

3. Epidemic investigation to identify whether there is a causal association between radiation and the outbreak of the unusual illness. For radiation incidents, case definition should be established, to confirm these cases. Their etiology is not so straightforward as it is for known infectious agents. This process may take some time and it will involve a multidisciplinary collaboration (e.g. environmental monitoring, scenario reconstruction, biological dosimetry). Along with confirming apparent cases, the outbreak management and investigation team should identify cases and define the scope of the problem.
4. Environmental health investigations are based on the preliminary findings of the epidemiological investigation. For example, if water is suspected to be the source of the illness, more resources will be directed to monitoring the water source.
5. As data accumulate during the outbreak, the public health team should generate descriptive epidemiologic information, and report findings to national competent authorities (which in turn will evaluate the need for notifying international bodies). These outbreaks are often highly visible and are conducted under intense public, political and media scrutiny. Communication between staff, departments, emergency services and government agencies, and communication with the media, is the key to preventing panic and achieving maximal control.

8 Prevention and treatment of psychological consequences

Psychosocial impact is one of the chief aims of terrorism. It presents significant challenges to medical community and health authorities and impacts at all levels of society. The health care system may be totally overwhelmed by people requesting advice, assessment and care, as a consequence.

A radiation emergency resulting from a malevolent act, is a highly stressful event. It may act as a powerful and persistent stressor, even after the emergency has been controlled. Psychological reactions following human made disasters, such as malevolent acts, are more intense and more prolonged than psychological reactions following natural disasters. They

may include multiple symptoms like fear, grief, anxiety, anger, depression and distrust. Psychosomatic symptoms are frequent and differential diagnosis and treatment of physical and psychological conditions will be essential during the early stage of the event, including the triage of casualties. (Berger and Sadoff, 2002).

Ionising radiation cannot be perceived by the senses and most people are unaware of the magnitude of its effects, which could result in community-wide feelings of helplessness and vulnerability. Those disasters with a high degree of uncertainty, regarding potential future health effects, are more psychologically traumatic than situations with more visible, immediate, and predictable outcomes. The fact that the control of the situation is out of citizens' hands increases the feeling of vulnerability in the population.

Radiation emergencies resulting from malevolent acts may affect the mental health of casualties, friends, relatives and responders. Emotional reactions in responders may be so intense and severe that they could even affect decision making and operations. These emergencies may also have an impact on people who have seen the event either first hand or through the media. Many people will fear possible exposure to radiation ("worried well") and could develop psychological symptoms. Casualties with radiation induced illness or injuries are at higher psychological risk than the worried well. They will often face long-term medical care, repeated surgery, isolation, rehabilitation, etc. Additional consequences, such as loss of the ability to work, financial problems and loss of self-esteem could increase the frequency and intensity of psychological reactions (Becker, 2001).

Parents with young children, pregnant women, children, elderly people, emergency workers, people with pre-existing mental disorders, clean up workers and evacuees, are at higher risk. Acute stress reactions typically observed include: physical, emotional, cognitive and interpersonal effects. Although many of them are transient and reversible mild to moderate reactions, early management of these symptoms can speed recovery and avoid long-term consequences (IAEA EPR-Medical, 2005; WHO, 2003).

There are mechanisms that societies have developed for better supporting crises. These implicit abilities to withstand the negative effects can be

partly acquired by previous experience, training, cultural features and individual personality. One of the best intervention strategies is to make use of those normal mechanisms to promote personal and societal cohesion. Psychiatric and psychologist teams should assist emergency medical staff to differentiate persons exhibiting psychosomatic symptoms from those patients with radiation-induced symptoms. The risk of either delay in therapy or administration of unnecessary medications should be avoided.

Wide-scale psychotherapy for the population is to be discouraged as this runs the risk of creating additional casualties. Instead, people should be referred to their family doctor (a general practitioner), in order to preserve the normal conditions and use the existing services. Most psychologists do not know about radiation risks or stochastic effects like cancer risks. For a well established therapy, it is better to refer to a psychologist with experience in dealing with cancer phobia or post-traumatic stress, who is also able to communicate risks. When psychological symptoms appear, they could be managed through conventional strategies i.e. psychotherapy and even psycho-pharmacotherapy, as routinely employed for anxiety and depression in other situations.

The psychological impact of traumatic events can last for weeks to months. A persistent state of alarm may result in chronic stress reactions involving behavioural, emotional and physiological consequences. Most people report feeling better within three months after a traumatic event. If the problems become worse or last longer, the person may be suffering from post-traumatic stress disorder (PTSD), characterised by persistent symptoms of irritability, anger, increased startle response and frequent re-experiencing of the accidental event. If PTSD develops, two types of therapies could be efficient: trauma focus therapy and cognitive behavioural therapy.

A smaller fraction of the population may develop more serious and persistent mental health problems such as: anxiety disorders, depression, alcohol or drug abuse and personality disorders. Higher incidences of psychosomatic symptoms, psychological distress and psychiatric disorders have been observed among casualties of radiation accidents. Decrements in performance on speed and accuracy tests and an increase in the prevalence of high blood pressure, cardiovascular diseases, digestive and neuroendocrine disorders, have been also found.

The psychosocial effects of radiation accidents may extent far beyond the area of impact because of the “anticipatory stress”. Long-term consequences may affect not only people exposed to ionising radiation but also those who have not been exposed but are concerned about “probable” and “imagined” future risks. The size of the population exhibiting chronic stress may be quite large and pervasive social stigma in residents of affected areas may exacerbate the problems, resulting in an increased burden on the health care system.

National preparation plans made before occurrence of emergencies should involve a system of coordination with specification of focal mental health spesialists, detailed plans to prepare for an adequate social and mental health response, and training of relevant personnel in social and psychological interventions (WHO, 2003). Because the psychosocial consequences of radiation emergencies can be as important as their biological and ecological impacts, psychosocial issues should be better integrated into emergency planning (Becker, 1997).

9 Taking decisions about long-term follow up of people involved in a radiation emergency

Medical monitoring programmes addressed at people involved in a radiation emergency should consider two different target populations:

- Persons who developed clinical conditions requiring medical assistance during the emergency (e.g. acute radiation syndrome, local radiation injuries); and
- Asymptomatic persons known (or presumed) to have been exposed to ionising radiation.

Long-term follow up of symptomatic persons is mainly aimed at the diagnosis and treatment of long-term complications and prevention and management of sequelae. The benefits of such medical monitoring programmes for symptomatic patients are clearly identifiable and their practical implementation does not substantially differ from the implementation of medical follow up of other medical conditions.

On the other hand, proper medical follow up of asymptomatic persons involved in a radiation emergency, poses major concerns related to the ability to identify populations at higher risk and to screen for disease in the population at risk in a manner that produces more benefits than harm. The goal is to detect disease in people without symptoms so that they can be treated earlier, on the assumption that earlier diagnosis will result in reduced morbidity and/or mortality.

During the emergency, basic relevant information needs to be in place (e.g. patient data in suitable worksheets) to facilitate epidemiological studies. Health care workers involved in the emergency should be aware of these needs. Specific advice will be requested, about the needs for further implementation of medical monitoring programmes, and health professionals in charge of managing the emergency should be capable of dealing with these requests (IAEA EPR-Medical, 2005; WHO, 2006; IAEA TECDOC 1300, 2002).

9.1 Long-term follow up of patients who developed local radiation injuries

Patients who suffered local radiation injuries, after moderate to high dose exposure, should be periodically monitored for many years. Patients will be advised to contact their family doctors/general practitioners (GPs) to report what happened and to plan the follow up programme. Although the follow up will be conducted by the family doctor, interaction with the relevant hospital department is recommended. Moreover, family doctors should interact with burn specialists, plastic surgeons, mental health professionals or other relevant health professionals, as necessary.

Telangiectasia and fibrosis are some of the characteristic late sequelae of local radiation exposure. According to the late radiation morbidity score (available at www.rtog.org/members/toxicity/late.html), late effects are those that appear 3 months or more after local radiation exposure. This late radiation morbidity scoring may also be applied to ensure common criteria for evaluation and categorisation of late symptoms and signs [Table K1]).

Table K1. Late radiation morbidity score according to the Radiation Therapy Oncology Group (RTOG) criteria.

ORGAN TISSUE	Grade 0	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Skin	None	Slight atrophy, pigmentation change, some hair loss	Patch atrophy; moderate telangiectasia, total hair loss	Marked atrophy; gross telangi-ectasia	Ulceration	Death directly related to radiation late effects
Subcu-taneous tissue	None	Slight induration (fibrosis) and loss of subcutaneous fat	Moderate fibrosis but asymptomatic, slight field contracture <10% linear reduction	Severe induration and loss of subcutaneous tissue, field contracture > 10 % linear measurement	Necrosis	
Mucous membrane	None	Slight atrophy and dryness	Moderate atrophy and Telangiectasia, little mucous	Marked atrophy with complete dryness, severe telangiectasia	Ulceration	

The follow up should be tailored case by case. Although there are no standard follow up protocols, some generic criteria similar to those applied to radiotherapy patients could be adapted to local radiation injuries (e.g. monthly clinical examination during the first three months, every third month during the first year, every 6-12 months the second year, and once a year thereafter).

The evolution of skin lesions must be recorded, preferably by colour photographs, making use of imaging diagnosis if necessary (e.g. ultrasound, thermography). Depending on the severity of the damage, the need for prevention/treatment of fibrosis (e.g. interferon, pentoxifyllin, alpha-tocopherol) should be considered and protocols for pain control implemented.

Mental health support and reproductive health counselling should be provided if required.

Periodical (e.g. annual) ophthalmological exams should be performed, particularly recording lens opacities (cataracts). Patients should know that they have to request medical advice in case of local infections, wounds or alarm signs such as erythema, oedema, pain, etc. Even after apparent healing, skin lesions may break down and acute inflammatory signs and symptoms may reappear. Due to the higher vulnerability of irradiated tissues, necrosis may be triggered even after mild mechanical, chemical or physical trauma. Recommendations to prevent additional damage in irradiated areas should be provided, including advice to avoid chemical exposures, mechanical trauma, sun exposure and exposure to extreme temperatures.

Radiation induced damage to the endothelium of blood vessels and functional disturbances the immunocompetent skin cells may alter protection against infections and healing processes. The management of infections in irradiated skin is of great importance.

Any planned surgical intervention (even minor) on the irradiated tissues or involving neighboring areas, should be carefully planned and agreed with the family doctor and relevant specialists.

9.2 Long-term follow up of casualties who developed acute radiation syndrome (ARS)

Persons who developed acute radiation syndrome (ARS) are at higher risk of developing long-term effects from ionising radiation. These effects include not only late deterministic effects (e.g. cataract, sterility, immune dysfunction) but also effects of a probabilistic nature, such as cancer.

Patients will be advised to contact their family doctors/GPs to report what happened and to plan the follow up programme. Although the follow up will be conducted by the family doctor, interaction with the relevant hospital department is recommended. Moreover, the family doctor should interact with hematologists, mental health professionals or any other relevant health professionals, as necessary.

Follow up should be tailored on a case by case basis, according to the severity of the ARS and individual organ doses (in cooperation with appropriate specialists). As an example, after recovery of aplasia, clinical and haematological examination may be performed every three months

during the first year; thereafter, a clinical routine examination may be conducted once a year.

Mental health support and reproductive health counselling should be provided, if required.

Periodic (e.g. annual) ophthalmological exams should be performed, particularly to record lens opacities (cataracts).

Follow up of stochastic effects (i.e. cancer) should not be indiscriminate since it may increase psychological morbidity. The peak of onset of leukaemia occurs 5 years after exposure, and most solid tumours appear well beyond 10 years after exposure. Even with the availability of an accurate test for early detection of cancer, there must be scientific evidence of the benefit of such early detection (availability of effective therapy, improvement of the clinical outcome). Effective use of specific tests/ screening depends on knowledge of their accuracy, their rate of false positive results, the appropriate interval for repeating them, as well as on their costs, unpleasantness and risks.

9.3 Long-term follow up of populations exposed to low doses

The epidemiological follow up of asymptomatic persons, after a radiation emergency, is implemented with the main purpose of detecting adverse effects or diseases potentially related to radiation exposure (e.g. cancer). (WHO, 2006).

For such screening to be beneficial:

- Disease risk should be identified in the population or population subgroups (e.g. children, pregnant women);
- An accurate practical screening tool must be available;
- Early detection of the disease must improve survival;
- Effective treatment of the disease needs to exist; and
- The benefits of the screening must be greater than the harm.

A radio-epidemiological study may be conducted with the following purposes:

- To identify adverse effects in a group of people known (or

presumed) to have been exposed to ionising radiation;
- To determine whether the risk of such effects is significantly greater in this group than for a comparable (e.g. age, gender) unexposed group of individuals;
- To determine whether the increased risk (if any) is statistically associated with the exposure;
- To determine if there is a relationship between the increased risk and other factors (e.g. tobacco smoking, exposure to chemicals);
- To derive and refine risk estimates; and
- To plan health interventions, as necessary.

Medical monitoring of people exposed to low doses must be carefully considered, taking into account legal, social, economic and psychological factors. There is not enough evidence to recommend follow up for stochastic effects (i.e. cancer), from a medical management perspective. However, in some cases, it is prudent to develop a registry and to conduct epidemiological research.

An epidemiological follow up study starts by identifying two target populations (those exposed and those unexposed) to determine whether these two groups experience different health outcomes.

In radiation epidemiology, cancer incidence or mortality are the typical outcomes. However, data emerging from the A-bomb survivors' life span studies indicate that other non-malignant morbidities and causes of mortality should also be included. Mortality is the most conclusive outcome to study for epidemiological purposes because its occurrence is clearly definable and relatively complete records are available in most countries. However, it is not always the health outcome of interest, since many non-fatal diseases, including cancers, may affect quality of life.

The size of the population that needs to be studied, to detect a statistically significant difference in mortality, increases dramatically (to hundreds of thousands or even millions) when the difference becomes small in comparison with the natural incidence of the disease of interest (UNSCEAR Report, 1993).

Several practical actions are involved in the planning and implementation of an epidemiological study in order to:

1. Determine the availability of an appropriate and clearly defined study population.
2. Ensure the correct identity and contact details of persons to be included in the registry.
3. Include relevant medical information in the initial registry (history of any injury and treatment given during the emergency).
4. Collect information about the magnitude and distribution of exposure (results of dose assessment, including effective dose, organ specific dose, ranges of doses received and projected, results of surveys for external and/or internal contamination, physical dose reconstruction, biodosimetry data).
5. Evaluate the accuracy with which the exposure can be determined.
6. Consider the background rate of the disease to be studied (e.g. cancer) and the expected increase in the incidence/mortality among the exposed group, based on current knowledge of radiation risks.
7. Determine the size and composition of the study population and control group needed taking into account the previous points;
8. Define inclusion and exclusion criteria for the study population and control group.
9. Apply objective criteria for inclusion of persons in the registry based on the potential for an increase in cancer morbidity/mortality (e.g. effective dose ≥ 100 mSv to the whole body).
10. Apply objective criteria for inclusion of exposed pregnant women that indicate a potential for an increase of consequences of prenatal exposure (e.g. effective dose ≥ 100 mSv to the foetus).
11. Ensure proper disease identification and recording (history of disease confirmed by hospital records, cause of death confirmed by death certificates).
12. Consider the inclusion of risk factors other than radiation that might affect the outcome.

CHAPTER L

International liaison

1 Introduction

Nuclear and radiological accidents, and situations resulting from malevolent acts involving radioactive material, can become a serious threat to life, health, the environment and society, over wide geographical areas. Relevant national authorities have the responsibility to decide upon and implement appropriate response actions, and to ensure that relevant resources are available for mitigation. However, the proper handling of severe nuclear and radiological emergencies, or situations where prompt response is warranted in order to mitigate the effects of a perceived hazard, may require resources that challenge the capabilities of a single country. It is therefore important for countries to cooperate in order to better respond to such emergencies and situations through the arrangements set up through formal mechanisms, such as, for example, the IAEA's Convention on Early Notification of a Nuclear Accident and Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (IAEA Legal series 14, 1987) or World Health Organisation's International Health Regulations (WHO, 2007b). Notwithstanding the binding character of the existing Emergency Conventions, they do not necessarily eliminate the need for the countries and organisation parties to these conventions, to have additional bilateral or multilateral agreements relating to information exchange or assistance.

2 International notification arrangements

In response to nuclear or radiological emergencies countries should use established notification channels as laid down by the protocols of the Early Notification Convention. It is therefore the responsibility of the relevant national authority to follow these arrangements. It is important to be fully aware of these protocols and ensure that local and/or national authorities are informed about the emergency/threat in a timely manner.

2.1 The Early Notification Convention

The Early Notification Convention was adopted in 1986, following the Chernobyl nuclear plant accident, and establishes a notification system for nuclear accidents which have the potential for international transboundary release that could be of radiological safety significance for another State (IAEA Legal series 14, 1987). It requires States to report the time and location of the accident, associated, radioactive releases, and other data essential for assessing the situation. Notification is to be made to potentially affected States directly or through the IAEA, and to the IAEA itself. Reporting is mandatory for any nuclear accident involving facilities and activities listed in Article 1. Pursuant to Article 3, States may notify other emergencies as well. The five nuclear weapon States (China, France, Russia, United Kingdom, and United States) have all declared their intention to also report accidents involving nuclear weapons and nuclear weapons tests.

On receiving the notification through the Emergency Notification and Assistance Convention ENAC web site or by fax the IAEA sends an initial message to all Member States. This is followed by further information as it becomes available. Information is also sent to all relevant international organisations including, among others, the European Commission (EC), the World Health Organization (WHO), the World Meteorological Organisation (WMO), and other organisations.

2.2 The European Commission Notification system

The European Community Urgent Radiological Information Exchange (ECURIE) system is the technical implementation of the Council Decision 87/600/Euratom on Community arrangements for the early notification and exchange of information in the event of a radiological or nuclear emergency (Euratom, 1987). This 87/600 Council Decision requires ECURIE Member States to promptly notify the EC and all the Member States potentially affected, when they intend to take countermeasures in order to protect their population against the effects of a radiological or nuclear accident. The EC will immediately forward this notification to all Member States. Following this first notification, all Member States are required to inform the Commission at appropriate intervals, about the measures taken and the radioactivity levels measured. All 27 EU Member States, as well as Switzerland and Croatia, have signed the ECURIE agreement.

2.3 World Health Organization

The current International Health Regulations (IHR) were put in place in response to the increased concerns about global health security (WHO, 2007b). The IHR are an international legal instrument that is binding on 194 State Parties around the globe. Their aim is to help the international community prevent and respond to acute public health risks that have the potential to cross borders and threaten people worldwide.

The IHR, which entered into force on 15 June 2007, require countries to report emergencies of public health concern to WHO through the national IHR focal point (NFP). NFPs are assigned for each national health authority. Building on the unique experience of WHO in global disease surveillance, alert and response, the IHR define the rights and obligations of countries to report public health events, and establish a number of procedures that WHO must follow in its work to uphold global public health security and assist its Member States to strengthen national capabilities for response. WHO is also a full party to IAEA's Emergency Conventions under which the Organization has a responsibility of providing medical and public health assistance (Carr, 2006; Souchkevitch, 1997).

3 Coordination of international assistance

In addition to standing bilateral and/or regional agreements, the affected country can request assistance from the IAEA through the Response Assistance Network (RANET) in the event of a serious emergency, where the efforts to manage and mitigate its consequences requires additional resources beyond a country's capability. One of the network's major objectives is to strengthen the IAEA's capability to provide assistance and/or to coordinate the provision of assistance, as specified within the framework of the Assistance Convention. As a result of the Assistance Convention, the World Health Organization established the Radiation Emergency Medical Preparedness and Assistance Network (REMPAN) in 1987. The network is designated to provide emergency medical and public health assistance to people over exposed to radiation. It also facilitates a long-term care and follow up of radiation accident casualties.

The magnitude and type of requested assistance depends on the situation: assistance may consist of technical consultations, a group of qualified experts deployed to the field, or it may consist of several specialised teams, particularly for complex situations. The resources and type of assistance needed will be identified and coordinated by the IAEA, and other relevant international organisations, the requesting state and state(s) providing assistance. The nature of the event will determine the participation of the appropriate international organisations, as defined in the Joint Radiation Emergency Management Plan of the International Organizations (IAEA, EPR-JPLAN, 2006). The Joint Plan defines the mechanism of response and the roles and responsibilities of each organisation, which can include, but is not limited to, WHO, WMO (World Meteorological Organization), FAO (UN Food and Agriculture Organization), EC (European Commission), Interpol and Europol [Figure L1].

All organisations co-sponsoring the Joint Plan, are members of the Inter-Agency Committee on Radiological and Nuclear Emergencies (IACRNE), which is a coordination mechanism to ensure that an effective emergency response capability is developed and maintained.

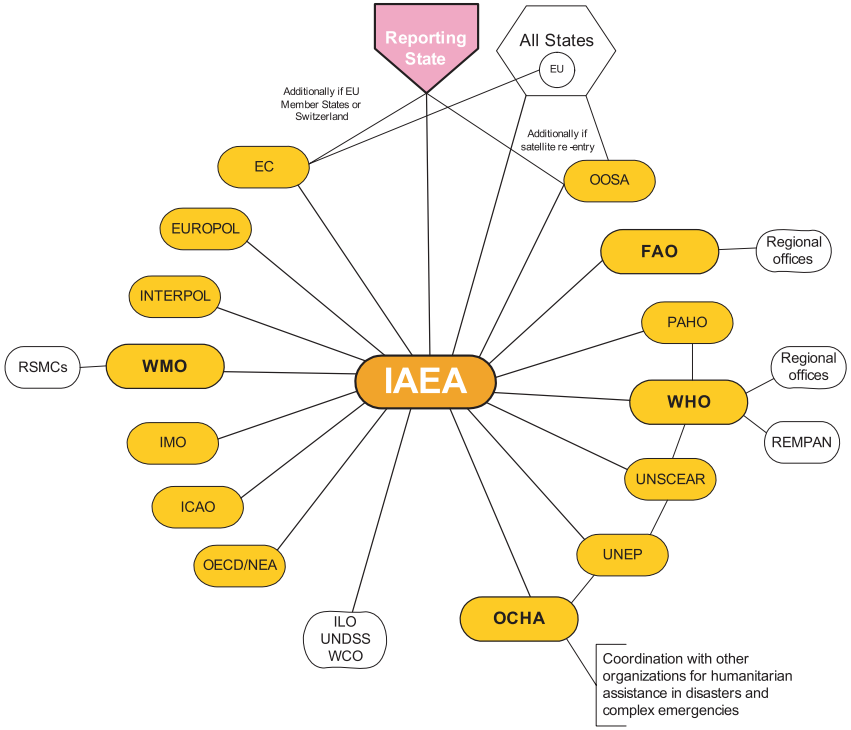


Figure L1. Framework for inter-agency response to nuclear or radiological emergencies. Reproduced courtesy of IAEA (IAEA EPR-JPLAN, 2006).

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Glossary

A

Abrasions: scraped area on the skin or on a mucous membrane, resulting from injury or irritation.
Absorbed dose: the amount of energy deposited by ionising radiation in a unit mass of tissue, expressed in units of joules per kilogram (J/kg), which is given the special name of "gray" (Gy).
Absorption Type: materials are absorbed from the respiratory tract to body fluids with different rates. Chemical compounds are generally allocated to one of three default Absorption Types. These are Type F (i.e. fast, for very soluble materials), Type M (for moderately soluble materials), and Type S (i.e. slow, for relatively insoluble materials).
Activity Median Aerodynamic Diameter (AMAD): in an aerosol containing radioactive particles with a range of sizes, fifty percent of the activity in the aerosol is associated with particles of aerodynamic diameter greater than the AMAD.
Acute Radiation Syndrome (ARS): a set of characteristic signs and symptoms observed after whole body or large volume partial body exposure.
Aerodynamic diameter: the diameter of the unit density spherical particle that has the same settling velocity in air.
Alpha (α) radiation: a positively charged particle emitted from the nucleus of some radioactive atoms when they decay. It generally carries more energy than gamma or beta radiation and deposits that energy very quickly while passing through tissue, referred to as "high linear energy transfer" (high LET). Alpha particles cannot penetrate the outer layer of the skin and, therefore, do not cause damage when outside the body. However, they may be particularly damaging if alpha emitters are inhaled or ingested.
Allogeneic: being genetically different although belonging to, or having been obtained from, the same species. This term is particularly used when talking about tissue grafts (e.g. skin graft or bone marrow transplantation).
Alopecia: loss of hair.
Analgesic therapy: therapy addressed to control or eliminate pain.
Anticipatory stress: stress caused by concern over the future.
Anti-emetic therapy: therapy addressed to prevent, stop, or relieve nausea and emesis (vomiting).

Antiphlogistic: an agent that counteracts inflammation.
Aplasia: failure to develop. Very often used to talk about haematopoietic failure ("bone marrow aplasia").
Asthenia: weakness, lack/loss of energy and strength.
Authorised personnel: assisting personnel such as police, fire fighters, medical personnel and drivers and crews of evacuation vehicles called upon to respond within the cordoned zones. In addition, radiation specialists, radiation protection officers and radiological assessors who may respond to emergencies, should be considered as authorised personnel.
Autograft: tissue transplanted from one part of the body to another in the same individual, also called an autotransplant.
Autologous recovery: functional recovery from cells of the same individual.

B

Becquerel: measure of the rate of radioactive decay that corresponds to one atomic disintegration per second. It is used as a measure of the amount of a radioactive material.
Beta (β) radiation: a charged particle ejected from the nucleus of a decaying atom. It includes electrons (negatively charged) and positrons (positively charged). Beta particles penetrate the outer skin layer, are not stopped in tissue as quickly as alpha particles, and produce less damage per living cell (low LET).
Bioassay: procedures to evaluate internal contamination, including external monitoring for gamma emitting radionuclides, whole body counting and lung counting (*in vivo* analysis), and radiochemical analysis of excreta (e.g. urine) and other samples (*in vitro* analysis).
Biodosimetry: see Biological dosimetry.
Biokinetics: in the field of radiation protection it refers to the kinetics of intake, distribution, retention and excretion of radionuclides in the body.
Biological dosimetry: use of biological samples, usually taken from individuals who have been exposed to ionising radiation, to directly measure biological endpoints that can be correlated to absorbed radiation dose. Quantification of chromosome aberrations in peripheral lymphocytes (cytogenetic dosimetry) is the method of choice. See also Dosimetry.
Blister: local swelling of the skin that contains watery fluid and is frequently caused by burning, infection, or irritation.
Bone marrow: the soft, fatty, vascular tissue that fills most bone cavities and is the source of most blood cells.

Brain oedema: also named cerebral swelling, it is an accumulation of fluids in the brain very often due to extravasation of fluid, plasma proteins, mainly albumin. Treatment can include diuretics and corticosteroids.
Buffer zone: region near the border of a protected or controlled area established as a transition zone.

C
Cataracts: opacity of the lens of the eye or its capsule (or both) that may result from injuries to the eye, ageing, exposure to great heat or radiation, or inherited factors.
Category P1: trauma triage category for severely injured people who require immediate life saving intervention.
Category P2: trauma triage category for people with less severe injuries (compared to Category P1) who will need hospital care, but whose transfer to a medical facility can be delayed for 10 – 12 hours.
Category P3: trauma triage category for injured people who will require medical care, but may wait for a number of hours or be told to go home and return the next day (the "walking wounded").
Chemical burns: tissue destruction caused by caustic agents, irritant gases, or other chemicals.
Clonogenic assays: experimental technique for studying the effectiveness of specific agents on the survival and proliferation of cells.
Combined injuries: radiation exposure in combination with burn, wound, trauma or infection.
Committed effective dose: the time integral of the effective dose rate that will be received by an individual following an intake of radioactive material. It is the effective dose that an individual is committed to receive once an intake has taken place. The integration period is 50 years for adults, and from intake to 70 years of age for children. The unit of committed effective dose is the sievert (Sv).
Conjunctival haemorrhage: haemorrhage that occurs beneath the conjunctiva, the transparent membrane covering the sclera.
Cord blood: blood collected after the cord has been detached from a newborn baby, which may be utilised as a source of haematopoietic stem cells for transplantation.
Cross contamination: spreading of radioactive materials from one person, object or place to another.
Cutaneous radiation syndrome: see Local radiation injury.

D
Decorporation (or internal decontamination): process of treatment for persons with internally deposited radionuclides aimed at eliminating the material from the body and reducing the internal dose from exposure and hence, reducing the risk of health effects.
Deterministic health effects: radiation induced health effects which occur only above a given threshold level of radiation dose. The severity of the effect is greater for a higher dose. Examples include *erythema* (skin redness) and *acute radiation syndrome*. Not all deterministic effects are early effects.
Detriment: see Health Detriment.
Dosemeter: general term applied to devices designed to record personal exposure to ionising radiation. Passive dosemeters include film badges and thermoluminescent dosemeters (TLDs), whilst active dosemeters include electronic personal dosemeters (EPDs). EPDs are designed to provide real time information on dose and dose rate. The dosemeter is the standard way of measuring personal exposure for the purposes of complying with statutory occupational dose limits.
Dose rate: the radiation dose delivered per unit of time.
Dose reconstruction: the process of estimating dose to people from radioactive contamination and/or exposure to an external source.
Dosimetry: methods to measure or assess the radiation dose to people or objects exposed to ionising radiation, including reading of badges worn by potentially exposed individuals as well as bioassay (e.g. measurement of activity in the body through samples of urine, faeces, etc.).

E
Early effects: radiation induced health effects that occur within some months after exposure. See also Late effects.
Effective dose: the sum of the equivalent doses to organs and tissues, weighted by the appropriate tissue weighting factors. These weighting factors represent the relative contribution of each organ or tissue to the total health detriment due to stochastic health effects resulting from uniform irradiation of the whole body. Effective dose provides a single quantity that can be used for radiation protection purposes to represent health detriment resulting from an intake of a radionuclide. The unit of effective dose is the sievert (Sv).
Emergency services: local public response organisations that are generally available and that perform emergency response functions. These may

include law enforcement, fire fighters and rescue brigades, ambulance services and control teams for hazardous materials.
Emergency worker: in the context of an incident involving ionising radiation, a worker who may be exposed in excess of occupational dose limits while performing actions to mitigate the consequences of an emergency for human health and safety, as well as severe consequences for property and the environment.
Emesis: vomiting.
Endarteritis obliterans: extreme degree of inflammation particularly affecting small arteries, accompanied by degeneration of the intima, leading to occlusion of the blood vessel.
Endogenous microbial flora: microorganisms found in various parts of the body such as skin, gut, mouth, upper respiratory tracts and genitals. Also called normal flora, this micro flora lives in harmony with the host. However, some types of flora are opportunists and seek to colonise when normal mechanisms of preventing disease are overcome (e.g. depression/ suppression of the immune responses).
Endothelium: layer of cells located at the interior surface of blood vessels, forming an interface between circulating blood and the rest of the vessel wall.
Environmental monitoring: see Monitoring, environmental.
Epilation: loss of hair. See also Alopecia.
Equivalent dose: the absorbed dose averaged over a tissue or organ, with the contribution from each radiation type (alpha, beta, gamma, etc.) weighted by a radiation weighting factor that reflects the effectiveness of that radiation in causing stochastic health effects. This effectiveness is sometimes called the radiation quality. The unit of equivalent dose is the sievert (Sv).
Erythema: redness of skin and/or mucosa.
Excoriation: erosion or destruction of the skin by mechanical means.
Exeresis: surgical removal of any part or organ; excision.
External contamination: radioactive material in the form of dust, solid particles, aerosols or liquid attached to a person's skin or clothes.
External contamination monitoring: Individual monitoring using measurements of the amount of radioactive material deposited on skin or clothing.
External monitoring: see Monitoring.

F
Fibrosis: development of excess fibrous connective tissue in an organ or tissue as a reparative or reactive process.
Field triage: all of those triage procedures that are carried out on the affected population outside of a hospital or other medical facility, either at the site of the incident or at a distance from it.
First Responder: the first members of emergency services to respond at the scene of an emergency.
Follow up: in this context, subsequent contact with a person for the purpose of monitoring health status following exposure, diagnosis and/or treatment.

G
Gamma dose rate (γ-DR): the absorbed dose that would be received per unit time by human tissue placed in a defined gamma radiation field.
Gamma (γ) radiation: high energy photons emitted by the nuclei of decaying atoms. Gamma radiation can penetrate through several metres of solid material.
Gastro-intestinal uptake factor (f_1): the fraction of material taken into the body by ingestion that is absorbed to body fluids as it passes through the gastro-intestinal tract. Chemical compounds are assigned a default value of f_1 between 0 and 1.
Graft rejection: in haematology, the expression is used to describe the situation when bone marrow infused during a transplant is rejected by the donor.
Graft Versus Host Disease: a serious complication of bone marrow transplantation where there is a reaction of donated bone marrow against the patient's own tissues.
Gray (Gy): the SI unit of absorbed dose, equal to 1 Joule kg^{-1}.
Granulocytopenia: reduced number of blood granulocytes, namely neutrophils, eosinophils, and basophils.

H
Haematopoiesis: formation of blood cellular components, which are derived from haematopoietic stem cells.
Haematopoietic stem cell: multipotent cells with the ability to become several different types of cell in the blood system.
Health detriment: a measure of the harm that would eventually be experienced by an exposed group and its descendants as a result of the

group's exposure to a source of ionising radiation.
Health surveillance: tracking and forecasting of any health event or health determinant through the collection of data, the integration, analysis and interpretation of those data into surveillance products (e.g. reports, advisories, alerts, and/or warnings), and the dissemination of those surveillance products to relevant public bodies. Surveillance products are produced for a specific public health purpose or policy objective.
Hereditary effects: radiation induced health effects that occur in a descendant of the exposed person (the less precise term "genetic effects" is also used). They are related to changes in germinal cells.
Histocompatibility: property of having the same, or mostly the same, alleles of a set of genes called the major histocompatibility complex (also called in humans HLA). These genes are expressed in most tissues as antigens to which the immune system makes antibodies. If the body is exposed to foreign antigens, e.g. by getting a tissue graft, it attacks the foreign material unless it is histocompatible.
Human mesenchymal stem cells (HMSC): multipotent cells that can differentiate either *in vivo* or *in vitro* into a variety of cell types such as myocytes (muscle cells), adipocytes, osteoblasts and hondrocytes.
Hyperkeratosis: thickening of the skin following production of an excess of proteins.
Hypotension: abnormally low blood pressure.

I
Immunocompetent skin cells: skin resident cells originating from the hematopoietic system participating in immune reactions.
Immunosuppression: act or effect that reduces the activation or efficacy of the immune system. Deliberately induced immunosuppression may be done to prevent the body from rejecting an organ transplant, to treat Graft Versus Host Disease after bone marrow transplant, or for the treatment of auto-immune diseases**.**
Individual monitoring: see Monitoring, individual.
Inpatient care: medical services provided to a person admitted for overnight stay in a hospital.
Internal contamination: radionuclides incorporated within the body as a result of inhalation, ingestion, direct absorption through open wounds or intact skin and mucosa.
Internal contamination monitoring: individual monitoring using measurements of the amount of radioactive material in the body.

Measurements may be direct (e.g. measurement of activity in the lungs using external detectors) or indirect (e.g. measurement of activity excreted in samples of urine).
Internal dosimetry: methods to assess the dose that a person is committed to receive as a result of an intake of a given amount of radioactive material.
Ionising radiation: for the purpose of radiation protection, radiation capable of producing ion pairs in biological material.
Isodose: a radiation dose of equal intensity to more than one body area. An isodose chart is a diagram of depth dose measurement at various positions within a radiation beam in which points of equal dose throughout the beam are joined to give isodose lines.

L
Laceration: a tear in the skin which results from a mechanical injury.
Late effects: radiation induced health effects that occur years after exposure.
Local radiation injury: injury to the skin and underlying tissues resulting from local exposure to a high external dose of ionising radiation.
Lymphocyte subpopulations: morphologically identical types of lymphocytes that can be distinguished by their cell surface antigens. Different subpopulations of lymphocytes play essential functions in human humoral or cell mediated immunity (i.e. immunity mediated by cells or by secreted antibodies).
Lymphocytosis: abnormal increase in the number or proportion of lymphocytes in the blood.
Lymphopenia: abnormal decrease in the number or proportion of lymphocytes in the blood.

M
Malevolence: the act of deliberately causing harm.
"Malevolent use": use characterised by malevolence.
Monitoring: the measurement of radiation dose or contamination, for reasons related to the assessment or control of exposure to radiation or radioactive material, and the interpretation of the results.
Monitoring, environmental: the measurement of external dose rates in the environment, or of widespread contamination by radionuclides of environmental media.
Monitoring, individual: monitoring using measurements of quantities of radioactive material in or on the body of the individual, or measurements

made by equipment worn by individual workers. It includes the assessment of radiation doses to the individual from the results of such measurements.
Monitoring, radiological: see Monitoring.
Monitoring, source: the measurement of the activity of radioactive material or of external dose rates in the localised area around a source.
Morbidity: in medicine this term can refer either to the state of being ill or to the degree or severity of a disease. In epidemiology, this term is also used to refer to the prevalence or incidence of a disease. The prevalence is the total number of cases, in a particular population at a particular point in time. The incidence is the number of new cases in a particular population during a particular time interval. The term morbidity rate can refer either to the incidence rate or to the prevalence rate of a disease (to compare, see also mortality).
Mortality: a measure of the number of deaths in a given population. Mortality rate is the number of people dying during a given time interval, divided by the total number of people in the population.
Multiple Organ Dysfunction (MOD): altered organ function involving two or more organ systems which may occur in acutely ill patients such that homeostasis cannot be maintained without intervention.
Multiple Organ Failure (MOF): a progressive condition usually characterised by combined failure of several organs such as the lungs, liver, kidney, along with some clotting mechanisms.
Myelosuppression: condition in which bone marrow activity is decreased, resulting in fewer red blood cells, white blood cells, and platelets.

N
Neovascularisation: proliferation of new blood vessels.
Neutropenic patient: patient with neutropenia, which is defined specifically as a decrease in the number of circulating neutrophils. See also Granulocytopenia.

O
Occupancy time: time spent by an individual at a given location.
Oedema: swelling of any organ or tissue due to accumulation of excess lymph fluid, without an increase of the number of cells in the affected tissue.
Omentum flap: omentum or epiplon is a large fold of peritoneum. In reconstructive plastic surgery, a segment of omentum, with its supplying blood vessels, may be transplanted as a free flap to a distant area.
Onycholisis: separation of the nail plate from the nail bed.

Operational Control Point (OCP): location established in the Red Zone on the Safety Perimeter to provide rapid access to the incident location for emergency personnel and where rapid initial screening measurements can be performed.
Outbreaks (or epidemics): occurrence of a disease in excess of its expected frequency.
Outpatient care: medical services that are provided without the need for an overnight stay in a hospital, e.g. through an ambulatory care clinic or emergency department.

P
P1, P2, P3: see Category P1, P2, P3.
Pancytopenia: medical condition in which there is a reduction in the number of red and white blood cells, as well as platelets.
Pemphigus: term that includes a group of rare autoimmune skin disorders characterised by the development of blisters in the outer layer of the skin (epidermis) and mucous membranes.
Personal Protective Equipment (PPE): specialised safety clothing or equipment worn for protection against health and safety hazards, especially in the work environment. Personal protective equipment may be designed to protect many parts of the body, i.e. eyes, head, face, hands, feet, and ears. Such equipment must be used when the existing risks cannot be sufficiently limited by other means.
Petechiae: small red or purple spots on the body, caused by a minor bleeding from broken capillary blood vessels.
Post traumatic stress disorder (PTSD): anxiety disorder that can develop after exposure to a highly stressful event or ordeal. Severe and ongoing emotional reaction to an extreme psychological trauma.
Proliferation response tests: in immunology, group of tests to evaluate the functional status of lymphocytes.
Public health: science and art of preventing disease, prolonging life and promoting good health.
Punctures: incision of tissues for injection of medication or for other diagnostic or therapeutic procedures.

R
Radiation burns: see Local radiation injury.
Radiation emergency medicine: emergency medicine related to the management of health effects resulting from radiation exposure of

individuals and populations.
Radiation protection: the protection of people from the effects of exposure to ionising radiation, and the means for achieving this.
Radioactive contamination: unwanted radioactive material inside the body or on the body surfaces (internal or external contamination, respectively). Contaminated persons are continually exposed to radiation until the contamination is removed.
Radioactive material: material emitting ionising radiation and designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity.
Radiation source: anything that may cause radiation exposure, such as by emitting ionising radiation or by releasing radioactive material, and can be treated as a single entity for protection and safety purposes.
Radioactive source: radioactive material that is permanently sealed in a capsule or closely bonded in a solid form and which is not exempt from regulatory control. This also includes any radioactive material released if the radioactive source is leaking or broken.
Radioactive waste: waste that contains, or is contaminated with, radionuclides at concentrations or activities greater than clearance levels established by the regulatory body.
Radiodermatitis: dermatitis (skin inflammation) due to exposure to ionising radiation.
Radiological dispersal device (RDD): any device that causes the purposeful dispersion of radioactive material without a nuclear detonation.
Radiological exposure device (RED): devices designed to cause external exposure to ionising radiation.
Radiological monitoring: see Monitoring.
Radiological triage: triage based on a consideration of actual or potential effects on health arising from exposure to ionising radiation.
Red Zone: the potentially hazardous area immediately surrounding an incident location.
Relative Biological Effectiveness (RBE): a relative measure of the effectiveness of different radiation types at inducing a specified health effect, expressed as the inverse ratio of the absorbed doses of two different radiation types that would produce the same degree of a defined health effect (the "degree" being probability for stochastic health effects, and severity for deterministic health effects).
Residual haematopoiesis: in the context of acute radiation syndrome, it refers to the functional activity remaining after bone marrow radiation damage.
Reverse isolation: a system designed to protect patients from getting an infection caused by germs – bacteria, viruses or fungi – that may be in the environment or carried by staff and visitors.

S
Safety Perimeter: the boundary of the Red Zone.
Security Access Control Point (SACP): a "gateway" on the Safety Perimeter providing controlled rapid access between the Red Zone and Yellow Zone.
Security Perimeter: the boundary of the Yellow Zone.
Sievert (Sv): the SI unit of equivalent dose and effective dose.
Somatic effects: radiation induced health effects that occur in the exposed person.
Source monitoring: see Monitoring, source.
Stab wound: a wound where the depth of injury is greater than the length and may come into contact with vital organs in the chest and abdomen.
Stochastic health effects: radiation induced health effects where the probability of occurrence is greater for higher radiation doses, but where the severity of the effects (if they occur) is independent of dose. They generally occur without a threshold level of dose and they may be somatic (i.e. they occur in the exposed person e.g. cancer) or hereditary effects (i.e. they occur in the descendant of the exposed person).
Stockpiles: in the context of public health, it refers to medical supplies stored, carefully accrued and maintained, so they can be made rapidly available when needed.
Strategic Command: the Strategic Command is in overall charge of the response to the incident, but is not present at the scene. The Strategic Command is likely to be headed by a senior member of the Security Forces (e.g. Police) or a senior member of local government.

T
Tactical Control Point (TCP): the location in the Yellow Zone from which on-site management and coordination takes place.
Tactical Incident Command (TIC): the TIC is in overall charge of all personnel operating at the site of the incident. It is likely to be led by the most senior member of the First Responder teams attending. The TIC reports to Strategic Command.
Telangiectasia: small dilated superficial blood vessels giving rise to

tenderness, pain or discomfort when an affected area is touched.
Tenderness: pain or discomfort when an affected area is touched.
Thermal burns: injuries to tissues caused by heat, characterised by degree, based on the severity of the tissue damage.
Thrombocytopenia: presence of sub-normal numbers of platelets in blood.
Transdermal absorption: absorption of a substance through the skin. It occurs through a slow process of diffusion, driven by the gradient between the high concentration in the delivery system and the zero concentration prevailing in the skin.
Trauma: any injury, whether physically or emotionally inflicted. Physical injury trauma may be caused by violent or disruptive action, or by the introduction into the body of a toxic substance. Psychological injury trauma can result from a severe emotional shock.
Trauma triage: triage based on degree of physical injury, see also Category P1, P2, P3.
Triage: the use of simple procedures for rapidly sorting people into groups based (a) on their degree of physical injury and (b) on actual or potential effects on health, and the allocation of care to these people so as to expedite treatment and maximise the effective use of resources.

U
Unrelated or partially matched donors: allogeneic (as opposite to autologous) hematopoietic cell transplantation remains a challenge due to the risk of graft rejection in the HLA mismatched settings. In the absence of matched sibling donors, alternative donors such as unrelated and/or partially matched family sources may be options.

W
Worried well: in emergencies, this term refers to people requesting assistance because they think they may have been exposed to a chemical, physical or biological agent, but who have not actually been exposed.

XYZ
Yellow Zone: the area surrounding the Red Zone from where personnel responding to the incident may operate, and where members of the public being evacuated from the Red Zone may be processed.

List of abbreviations

α:	alpha radiation
β:	beta radiation
γ:	gamma radiation
γ-DR:	gamma dose rate
μm:	micro metre (10^{-6} m)
μSv:	micro Sievert
ABC:	Airway, Breathing and Circulation
AL:	Action Level
ALI:	Annual Limit on Intake
AMAD:	Activity Median Aerodynamic Diameter
ANC:	Absolute Neutrophil Count
ARS:	Acute Radiation Syndrome
BM:	Bone Marrow
Bq:	becquerel
BS:	Body Surface
CBC:	Complete Blood Count
CBMN:	Cytokinesis Block Micronucleus Assay
CBRN:	Chemical, Biological, Radiological, Nuclear
CCTV:	Closed-Circuit Television
CLOR:	Central Laboratory for Radiological Protection in Poland
cm:	centimetre
cps:	counts per second
CRP:	C-Reactive Protein
CRS:	Cutaneous Radiation Syndrome
CT:	Computed Tomography
DG Research:	Directorate General Research
DTPA:	Diethylene Triamine Pentaacetic Acid

E_{50}:	Committed Effective Dose (Adult)
E_{70}:	Committed Effective Dose to age 70 (Children)
EC:	Electron Capture
EC:	European Commission
ECG:	Electrocardiogram
EEG:	Electroencephalogram
EPO:	Erythropoietin
EPR:	Electron Paramagnetic Resonance
ESR:	Electron Spin Resonance
EU:	European Union
Euratom:	European Atomic Energy Community
f_1:	Gastro-Intestinal Uptake Factor
FAO:	Food and Agriculture Organization
FISH:	Fluorescence *in situ* Hybridisation
Flt3:	Ligand for the FLT3 Tyrosine Kinase Receptor
G-CSF:	Granulocyte Colony-Stimulating Factor
GI:	Gastro Intestinal
GM-CSF:	Granulocyte-Macrophage Colony-Stimulating Factor
GP:	General Practitioner
GPS:	Global Positioning System
GVHD:	Graft Versus Host Disease
Gy:	gray
h:	hour
HLA:	Human Leukocyte Antigen
HPA:	Health Protection Agency
HSC:	Human Stem Cell
HSCT:	Human Stem Cell Transplantation
IACRNE:	Inter-Agency Committee on Radiological and Nuclear Emergencies
IAEA:	International Atomic Energy Agency
ICRP:	International Commission on Radiological Protection
ICU:	Intensive Care Unit

ID:	Identity
IHR:	International Health Regulations
IR:	Ionising Radiation
IRSN:	Institut de Radioprotection et Sureté Nucléaire
KGF:	Keratinocyte Growth Factor
KI:	potassium iodide
LiI:	lithium iodide
LRI:	Local Radiation Injury
LSA:	Low Specific Activity
m:	metre
MDA:	Minimum Detectable Activity
METREPOL:	Medical Treatment Protocols for radiation accident victims
MN:	Micronucleus
MOD:	Multi-Organ Dysfunction
MOF:	Multi-Organ Failure
MRI:	Magnetic Resonance Imaging
MSC:	Mesenchymal Stem Cells
mSv:	milli sievert
NaI(Tl):	sodium iodide doped with thallium
NCRP:	National Council on Radiation Protection & Measurements
NFP:	National Focal Point
NHS:	National Health Service
NIRS:	National Institute of Radiological Sciences
NMR:	Nuclear Magnetic Resonance
NRPA:	Norwegian Radiation Protection Authority
NSAID:	Non-Steroid Anti-Inflammatory
OCP:	Operational Control Point
OILs:	Operational Intervention Levels
OSL:	Optically Stimulated Luminescence
P1, P2, P3:	Category P1, P2 and P3 casualties
PCC:	Premature Chromosome Condensation
PPE:	Personal Protective Equipment

PRD:	Personal Radiation Detector
PTSD:	Post Traumatic Stress Disorder
RANET:	Response Assistance Network (IAEA)
RBE:	Relative Biological Effectiveness
RC:	Response Category
RDD:	Radiological Dispersal Device
REAC/TS:	Radiation Emergency Assistance Center/Training Site
RED:	Radiological Exposure Device
REMPAN:	Radiation Emergency Medical Preparedness and Assistance Network
RN:	Radionuclide
SACP:	Secure Access Control Point
SCF:	Stem Cell Factor
SCO:	Surface Contaminated Object
SCK•CEN:	Studiecentrum voor Kernenergie. Centre d'Étude de l'Energie Nucléaire (Belgian Nuclear Research Centre)
STUK:	Radiation and Nuclear Safety Authority in Finland
Sv:	sievert
TBI:	Total Body Irradiation
TBSA:	Total Body Surface Area
TCP:	Tactical Control Point
TIARA:	Treatment Initiatives After Radiological Accidents
TIC:	Tactical Incident Command
TLD:	Thermoluminescent Dosemeter
TMT:	Triage, Monitoring, Treatment
TPO:	Thrombopoietin
UK:	United Kingdom
US:	United States
WBC:	Whole Body Counter
WBI:	Whole Body Irradiation
WHO:	World Health Organization
WMO:	World Meteorological Organization

Annexes

Annex 1: Required facilities

This Annex contains brief information on permanent laboratory facilities. Information relating to temporary facilities is given in Annex 2. The information presented here is intended to be used for planning relating to the establishment of laboratory facilities required to deal with the type of incident addressed by this Handbook. For detailed technical information on the equipment needed, reference should be made to the extensive literature that exists for such laboratory facilities.

This Handbook may be used by countries with differing levels of investment in such permanent facilities. Therefore, a distinction is made here between the facilities that ought to be available in each country; facilities that ought to be available, but not necessarily within the country (and could be made the subject of arrangements to share resources with neighbouring countries); and facilities that are desirable but not essential, either within the country or in neighbouring countries.

Facilities that ought to be available in each country

1. **Buildings or establishments that could be used as a Reception Centre**
   - Examples are sport centres or schools;
   - Areas for accommodating large numbers of people are needed; and
   - Simple decontamination facilities are needed – showers, changing areas.

   The suitability of the general type of building should be confirmed in advance.

2. **Whole body monitoring laboratory**

   Outline specification:
   - Room with walls of iron or other shielding material;
   - High-purity germanium or NaI(Tl) detector(s);
   - Detector(s) calibrated to cover the energy range of at least 60 keV to 2000 keV;

   - Geometries with a stretcher or chair and a single or multiple detectors could be used;
   - Suitable hardware and software for collection and analysis of spectra. Hardware capable of dealing with high count rates is desirable; and
   - Phantoms for efficiency calibration of the measurement system.

3. **Laboratory for measurement of gamma-ray emitters in bioassay and environmental samples**

   Outline specification:
   - High-purity germanium detector(s);
   - Detector shielded on all sides by 100 mm of lead (or alternative material giving similar shielding factors). Graded lining preferred;
   - Detector calibrated to cover the energy range of at least 60 keV to 2000 keV;
   - Detectors suitable for measurements of gamma-ray and X-ray emissions from about 10 to 60 keV are desirable;
   - Suitable hardware and software for collection and analysis of spectra. Hardware capable of dealing with high count rates is desirable;
   - A range of sample containers suitable for measurement of liquids, soils and vegetation samples. Filters suitable for measurement of airborne particles must be available;
   - Efficiency calibration factors (relating measured full energy peak areas to sample activity) for the sample containers and environmental materials to be measured; and
   - Laboratory facilities for preparation of samples.

4. **Peripheral health care centres**

   Outline specification:
   - Laboratory with capability for carrying out total blood cell counts and white blood cell differential counts; and
   - Primary health care facilities for diagnosis and outpatient care.

5. **Local hospitals (health care level 1)**

   Outline specification:

   - Facilities for outpatient, inpatient and emergency care including diagnosis technical units (e.g. diagnostic imaging service and laboratory) and capacity to act as a referral hospital for primary health care centres;
   - Emergency care service as a 24-hour facility equipped to address major vital medical or surgical needs, with access to diagnostic exams (imaging and laboratory); and
   - Laboratory with capability for carrying out:
     - Total blood cell counts and white blood cell differential counts;
     - Basic coagulation profile;
     - Electrolytes and routine serum biochemical profile; and
     - Urine analysis

6. **Secondary referral hospitals (health care level 2)**

   Outline specification:

   - Facilities for outpatient, inpatient and emergency care including diagnosis technical units (e.g. diagnostic imaging service and laboratory) and capacity to act as a referral for primary hospitals in the field of:
     - Internal medicine including emergency care;
     - General surgery;
     - Special care unit;
     - Haemotherapy;
     - Haematology;
     - Obstetrics;
     - Gynaecology;
     - Pediatrics;
     - Mental health care; and
     - Specialised diagnostics, such as CT scans and MRIs.

7. **Tertiary referral hospitals (health care level 3)**

   - Facilities for outpatient, inpatient and emergency care including diagnosis technical units (e.g. diagnostic imaging service and laboratory) and capacity to act as a referral for secondary hospitals in the field of:

     - Full intensive care unit;
     - Specialised burns intensive care unit;
     - Specialised care unit for immunosuppressed patients;
     - Bone marrow transplantation unit;
     - Specialised surgery;
     - Gastroenterology
     - Advanced medical imaging technologies; and
     - HLA typing and other advanced laboratory technologies.

Facilities that ought to be available, but not necessarily within the country

8. **Radiochemistry laboratory capable of carrying out the sample preparation necessary for measurements of alpha and beta emitting radionuclides:**

   - Equipped for bioassay sample analysis and environmental sample analysis; and
   - Analytical methods for the radionuclides specified in Table H1 [Section H.2.5].

9. **Laboratory for measurement of alpha emitting and beta emitting radionuclides.**

10. **Laboratory equipped for cytogenetic measurements on blood samples.**

    Outline specification:

    - Capability for carrying out blood cell counts;
    - Cell culture facilities; and
    - Microscopy and image analysis systems for cytogenetics.

11. **Laboratory for electron spin resonance measurements (ESR)**

    - ESR spectrometers.

12. **Facilities and equipment for performing dose reconstruction guided surgery in severe local radiation injuries**

Desirable facilities

13. Transportable environmental monitoring unit

Outline specification:

- Dose rate monitoring;
- Radionuclide identification;
- Aerosol sampling;
- Sample and *in situ* gamma spectrometry;
- Alpha spectrometry; and
- Data communications tools.

Such facilities would be particularly useful in countries where the availability of fixed facilities is limited, or where existing facilities are centralised at a single location.

14. Transportable body monitoring unit

Outline specification:

- Must be readily transportable to the scene of the incident;
- A high-purity germanium detector is preferable, but a NaI(Tl) detector may also be used;
- Detector calibrated to cover the energy range of at least 60 keV to 2000 keV;
- Shielding to reduce the effect of environmental contamination is preferable;
- Efficiency calibration factors relating full energy peak areas to activity in whole body. Calibrations factors must be available for children as well as adults;
- A system suitable for measurement of gamma-ray and X-ray emitters less than 60 keV in lung is desirable;
- Suitable hardware and software for collection and analysis of spectra;
- Hardware capable of dealing with high count rates is desirable;
- Measures needed to protect the equipment from radioactive contamination; and
- Data communications tools.

Such facilities are likely to have a significantly higher throughput than laboratory facilities.

15. Mass decontamination facilities

Outline specification:

- Showers should be used for decontamination; ideally the correct percentage of detergent should be mixed with the water;
- Areas must be available for undressing and dressing;
- Consideration must be given to people's comfort and modesty needs;
- Clean, dry clothing must be provided;
- Facility should be capable of being erected in a few minutes;
- System should be designed to decontaminated people at a rate of about 200 per hour;
- Facilities should be available to heat the water used for decontamination;
- It should be possible for people who are unable to walk to use the facility (or provide an alternative); and
- Water used for decontamination should be contained if possible. (However, waste water considerations must not delay decontamination of people).

Annex 2: Equipment required for radiological triage and monitoring purposes

This annex provides a list of supplies required to carry out the procedures described in Chapters E to I. Permanent facilities such as laboratories are described in Annex 1 and measurement equipment in Annex 8. The availability of this equipment will need to be confirmed in advance of any incident.

Personal Protective Equipment (PPE)

In all cases, alternative PPE giving a similar level of protection may be used.

A. First responders and emergency workers entering the Red Zone

- Full face respirator;
- Waterproof gloves (must be abrasion resistant);
- Waterproof clothing (all skin and hair must be covered);
- Waterproof shoes or boots;
- Safety helmet;
- Alarming personal dosemeter (measuring instantaneous dose rate as well as cumulative dose);
- A personal dosemeter (film badge or thermoluminescent dosemeter (TLD); and
- High visibility clothing is recommended.

Figure A2.1. Full face mask and filters are the basic respiratory protection for CBRN units. A correctly fitted full face mask should not have an inward leakage above 0.05 %. Filters are classified into P1, P2 and P3 classes with filter penetration less than 20 %, 6 % and 0.05 %, respectively. Class P3 filters should be used with full face masks to obtain the best protection factor. Photo: STUK.

Figure A2.2. Non-gas-tight (Type 2) protective suits against liquid and gaseous chemicals are basic protective clothing for the CBRN units. They provide excellent protection in radiological emergencies. In most cases, they are not needed for personnel working outside the Red Zone. Photo: STUK.

B. First responders and emergency workers entering the Yellow Zone and medical staff handling contaminated casualties

- Simple respirators/dust masks;
- Surgical gloves, which should be changed frequently;
- Coveralls;
- Plastic shoe covers;
- Hair cover (e.g. surgical cap); and
- A personal dosemeter (film badge or thermoluminescent dosemeter (TLD) is recommended).

Figure A2.3. Filtering facepieces (FFP) are classified into three classes FFP1, FFP2 and FFP3 with filter material penetration factors less than 20 %, 6 % and 1 %, respectively. Extra inward leakage from the edges lead to total allowed inward leakages less than 22 %, 8 % and 2 %. Only FFP3 filtering facepieces give a good protection factor (NPF 50) for prolonged exposures. They are adequate for personnel working outside the Red Zone. Photo: STUK.

Figure A2.4. Protective clothing against particulate radioactive contamination is categorised into three classes 1, 2 and 3 with nominal protection factors of 5, 50 and 500, respectively. Basic "dust-proof" coveralls fall into class 1. The compatibility with different types of respiratory protection should be checked. All hood designs do not work well with full face masks. They are usually designed to be used with filtering facepieces and may leave skin exposed between the hood and the full face mask. Photo: STUK.

C. Personnel carrying out decontamination of people
As in B. In addition waterproof clothing is recommended.

Standards for Personal Protective Equipment (PPE)

Respiratory protective devices (EN 133)

- Filtering devices:
  - Full face mask (EN 136) + filter (EN 143)
  - Half face mask (EN 140) + filter
  - Filtering facepieces (EN 149, EN 405); and
- Breathing apparatus:
  - Self-contained open-circuit compressed air breathing apparatus - SCBA (EN 137).

Protective clothing

- Protective clothing against particulate radioactive contamination (ventilated EN 1073-1, non-ventilated EN 1073-2); and
- Gas-tight (Type 1) or non-gas-tight (Type 2) protective clothing against liquid and gaseous chemicals including liquid aerosols and solid particles (EN 943-1):
  - Type 1 suits are reusable
  - Type 2 suits are either reusable or disposable.

Equipment to mark and limit contamination and to cover and store items

- Vinyl examination gloves;

- Coveralls of different sizes;
- Plastic shoe covers;
- Paper towels, disposable wipes;
- Adhesive disposable mats;
- Plastic bags, small for personal belongings and larger for contaminated waste;
- Coloured and clear tape;
- Adhesive labels;
- Blankets or lightweight aluminium wraps; and
- Instrument manuals.

Specification of zone boundaries

- Detailed maps of the area;
- Barrier system (vehicles, cones, signage, tape/rope or paint for road/ground/floor) with well defined exit points; and
- Monitoring equipment (see below).

Decontamination of people: Personal decontamination equipment

- Moist towels or disposable wipes;
- Towels;
- Large plastic bags (a variety of sizes to hold clothing);
- Plastic bags for small personal items;
- Adhesive labels;
- Soap (mild) or liquid soap;
- Shampoo (no conditioner);
- Plastic sponges;
- Soft nail brushes;
- Replacement clothing (various sizes are needed including very large as well as children's sizes);
- Blankets; and
- Saline/medical dressings/gauze.

Forms and telecommunications equipment

- Informational fact sheets to distribute to people at various locations [Annex 3];
- Record forms for registration, triage and external and internal monitoring [Annex 3];
- Notebooks;
- A reliable means of 2-way communication with the control centre (note that mobile phone networks may not be reliable);
- GPS equipment;
- Telephone and facsimile machine;
- Computers (laptops) and internet connectivity (if possible);
- Photocopiers or scanner; and
- Barcode generators and readers for labelling people and forms (if possible).

Monitoring

Portable monitoring equipment [Annex 8] is needed for:

1. Dose rate monitoring;
2. Contamination surveys;
3. Monitoring external contamination of people; and
4. Monitoring internal contamination of people.

The equipment needed comprises:

- Gamma dose rate monitoring equipment;
- Personal alarming dosemeters (these should be capable of measuring instantaneous dose rate as well as cumulative dose);
- Alpha contamination monitors;
- Beta contamination monitors. Instruments capable of detecting both alpha and beta contamination could be used, but must be able to distinguish between alpha and beta contamination;
- Gamma contamination monitors;
- Hand held monitors for measuring neutron dose rate;
- X-ray and low energy gamma contamination monitors;

- Portable gamma spectrometry equipment;
- Equipment to take wipe samples [Annex 8];
- Equipment to take nasal swab samples [Section F.3.4.2];
- Plastic bags to cover monitors (alpha contamination monitors must not be covered); and
- Personal protective equipment for monitoring teams (see above).

Annex 3: Forms, questionnaires and information leaflets

This annex provides examples of forms, questionnaires and information leaflets that could be adapted to fit a given incident/accident.

A3.1 Information sheet for Environmental Monitoring Team

A3.2 Results of field measurement made by the Environmental Monitoring Team

A3.3 Registry form for person involved in the emergency

A3.4 External contamination survey report

A3.5 Internal contamination report form

A3.6 Radionuclide/Organ specific measurements

A3.7 *In vitro* bioassay measurement report

A3.8 Individual dose assessment report form

A3.9 Emergency personnel dose follow up form

A3.10 Example report letter to members of the public for measurements less than the method detection limit

A3.11 Example report letter for assessed doses less than 1 mSv

A3.12 Example report letter for assessed doses greater than 1 mSv and less than the lower action level (maximum 20 mSv)

A3.13 Medical information form

A3.14 Information for family doctors in the event of an incident involving radiation

A3.15 Information to people who have been found to be contaminated with radioactive material

A3.16 Information to people who might have been exposed to radiation/ radioactive material

A3.17 Examples of press releases

A3.1 Information sheet for Environmental Monitoring Team

Incident code			
Did the incident happen at a specific location?	Yes/No	If yes, please indicate the location: Address: Inside / Outside Floor number:	
Room number:			
What radiation type is involved?	alpha Yes/No	beta Yes/ No	gamma Yes/No	neutron Yes/No
What radionuclides are involved?	1.	2.	3.	4.
Source Intact	Yes / No / Unknown Details:		
Contamination present	Yes / No / Unknown Details:		
Irradiation source removed	Yes / No / Unknown Details:		
Map showing source location	Available? Yes /No	Provided to team? Yes / No	
Map showing distribution of contamination	Available? Yes /No	Provided to team? Yes / No	
Conventional Hazard Present	Fire / Chemicals / Biological / Unstable buildings / Other Give Details:		
Personal Protective Equipment required	Respiratory Protection	Yes / No	Details
	Gloves	Yes / No	Details
	Waterproof clothing	Yes / No	Details
	Waterproof shoes/ boots	Yes / No	Details
	Safety Helmet	Yes / No	Details
	Alarming dosemeter	Yes / No	Details
	Personal dosemeter	Yes / No	Details
	High visibility clothing	Yes / No	Details
	Other	Yes / No	Details

Equipment Required	Gamma dose rate monitor	Yes / No	Details	
	Neutron dose rate monitor	Yes / No	Details	
	Beta dose rate monitor	Yes / No	Details	
	Gamma contamination monitor	Yes / No	Details	
	Beta contamination monitor	Yes / No	Details	
	Alpha contamination monitor	Yes / No	Details	
	Portable gamma spectrometer	Yes / No	Details	
	Equipment for wipe samples	Yes / No	Details	
	Air sampling equipment	Yes / No	Details	
	Environmental sampling equipment	Yes / No	Details	
	GPS	Yes / No	Details	
	Radio	Yes / No	Details	
	Other	Yes / No	Details	
What kind of measurements are requested?	Gamma dose rate measurements	Yes / No	Locations?	Expected dose rates, if known.
	Neutron dose rate measurements	Yes / No	Locations?	Expected dose rates, if known.
	Alpha contamination	Yes / No	Locations?	Expected levels, if known.

	Beta contamination	Yes / No	Locations?	Expected levels, if known.
	Gamma contamination	Yes / No	Locations?	Expected levels, if known.
	Air samples	Yes / No	Locations?	

A3.2 Results of field measurement made by the Environmental Monitoring Team

| Incident code | | |

Incident Code:		
Unique Person Code:		
D. Radiological Triage based on clinical signs and symptoms		
	Has the person been assigned to trauma triage category P2 or P3?	Yes/No If yes, refer to Figure F1 and Section F.2.2.2.
	Has the person been in the Red Zone at any time since the incident?	Yes/No If yes, refer to Section F.2.2.2.
	Has the results of individual monitoring indicated that the Upper Action Level has been exceeded (Section H.4)?	Yes/No/Results not yet available If yes, refer to Figures H3 and H4.
A2. Supplementary Personal Information		
e-mail address		
Current Address:	Apartment Number:	
	House number/Name:	
	Street:	
	Town:	
	Post Code:	
	Country	
Name and address of next of parent/guardian/ responsible person	Forenames	
	Family Name	
	Apartment Number:	
	House number/Name:	
	Street:	
	Town:	
	Post Code:	
	Country	
Name and address of family doctor	Family Name	
	House number/Name:	
	Street:	
	Town:	
	Post Code:	
	Country	
B2. Supplementary Information - External Irradiation Incident		
	Did direct physical contact with source take place?	Yes/No If yes, then assign to high priority and refer to Instructions F.16 and F.23.
	Time of day of closest approach to source	HH:MM ____:____
	Distance of closest approach to source	0-1 m ☐ 1-5 m ☐

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Incident Code:		
Unique Person Code:		
		5-10 m ☐ 10-30 m ☐ Other (specify): _____
	Time spent at closest approach	More than 1 hour ☐ Between 30 minutes and 1 hour ☐ Between 5 minutes and 30 minutes ☐ Less than 5 minutes ☐ Other (specify) _____
	If incident took place in a building was the person in:	Same building / Different building to the incident location
	If incident took place in a building was the person on:	Same floor / Different floor to the incident location
	If incident took place in another enclosed space was the person on:	Same _____as source, Yes/No (e.g. railway platform)
Assigned Priority	For triage based on location. See Instruction F.21.	Low/Low-Moderate/Moderate/Moderate-High/High
Samples	Has the person provided a sample for a blood cell count? See Instruction F.33.	Yes/No If yes, date and time sample taken Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
	Has the person provided a sample for cytogenetic measurements? See Instruction F.36.	Yes/No If yes, date and time sample taken Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
C2. Supplementary Information - Environmental Contamination Incidents		
	Was there any direct contact with released material?	Yes/No If yes, then assign to high priority and refer to Instruction F.19 and sequence
	Was the person inside or outside?	Inside/Outside
	Time of day at this location	HH:MM ____:____
	If outside, distance from the source of contamination (in metres)?	0 - 400 m ☐ > 400 m ☐
	If outside, length of time at this location?	More than 1 hour ☐ Between 30 minutes and 1 hour ☐ Between 5 minutes and 30 minutes ☐ Less than 5 minutes ☐ Other (specify) _____
	If incident took place in a building was the person in:	Same building / Different building to the incident location
	If incident took place in a building was the person on:	Same floor / Different floor to the incident location
	If incident took place in another enclosed space was the person on:	Same _____as source, Yes/No to the incident location
Assigned Priority	For triage based on location. See Instruction F.20.	Low/Low-Moderate/Moderate/Moderate-High/High

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Incident Code:		
Unique Person Code:		
Measurements, Procedures and Samples	Has the person been screened for external contamination? See Section F.3.3.	Yes/No If yes, date and time of measurement Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
	Has the person been screened for internal contamination? See Section F.3.4.	Yes/No If yes, date and time of measurement Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
	Has the person been through a decontamination procedure? See Chapter G.	Yes/No If yes, date and time of decontamination Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
	Has the person had a body monitoring measurement? See Section H.3.	Yes/No If yes, date and time of measurement Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
	Has the person provided a urine sample?	Yes/No
	Has the person provided a faecal sample?	Yes/No
	Has the person provided a nose blow/nasal swab sample?	Yes/No
	Has the person provided a sample for a blood cell count? See Instruction F.33.	Yes/No If yes, date and time sample taken Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
	Has the person provided a sample for cytogenetic measurements? See Instruction F.36.	Yes/No If yes, date and time sample taken Date (dd/mm/yy) ___/___/__ Time (HH:DD) ____:____
E. Form completed by:	Full Name	
Organisation:		
Date:		

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A3.4 External contamination survey report

Unique Person Code: _____

Forename(s): _____ Sex: ☐ M ☐ F
Family Name: _____
Date of birth: _____

Date of measurement before decontamination (dd/mm/yy):_____/_____/_____
Time of measurement (HH:DD): _____
Instrument type: _____ Model: _____
Background reading (cps): _____ Detector active surface: _____ [cm^2]
Conversion Factor (cps/Bq cm^{-2}) _____
Reading from person, for portal monitors (cps) _____ Portal Monitor Model:_____

Front	Count rates before and after decontamination	Back
	Before_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps** **Before**_____**cps** **After**_____ **cps**	

Remarks: Indicate count rate readings in the centre of the diagram. Indicate location of the readings by arrows and circle/shade areas of contamination. Only record readings greater than background.

Decontamination procedures performed: ☐ Yes ☐ No provide more details as follows:
If "Yes" details of decontamination procedures (use additional pages if needed)_____
_____
_____

Date of measurement after decontamination (dd/mm/yy):_____/_____/_____

Time of measurement (HH:MM): _____:_____

Instrument type: _____ Model: _____

Background reading (cps): _____ Detector active surface: _____ [cm^2]
Conversion Factor (cps/Bq cm^{-2}) _____
Reading from person, for portal monitors (cps) _____ Portal Monitor Model:_____
Remarks:_____
Surveyed by:
Organisation:

A3.5 Internal contamination report form

Unique Person Code:

Forenames: _____ Sex: ☐ M ☐ F

Family Name: _____
Age: _____

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

Radionuclide(s) _____

Decontamination procedures performed prior to measurement: ☐ Yes ☐ No

Stable iodine taken: ☐ Yes ☐ No
If yes, time of administration (HH:MM) _____
Date of administration (dd/mm/yy) _____

Subject weight (if recorded), kg _____

Whole Body Measurements of high energy gamma emitters using dose rate instruments

Instrument type: _____ Model: _____
Distance from person to instrument (cm) _____
Background reading (μSv/h): _____
Reading from person (μSv/h): _____
Calibration Factor (Bq/μSv/h): _____
Activity, if calculated (Bq) _____

Whole Body and Thyroid Measurements of high energy gamma emitters using simple instruments

Instrument type: _____ Model: _____
Measurement geometry: _____
Distance from person to instrument (cm) _____
Background reading (cps): _____
Reading from person (cps): _____
Calibration Factor (Bq/cps): _____
Activity, if calculated (Bq) _____

A3.6 Radionuclide/Organ specific measurements

Instrument type: _____
Reference Date: dd/mm/yy ____/____/____

Radionuclide	Type of measurement*	Measured Activity, Bq	Measurement Uncertainty, Bq

* indicate if whole body, lung, thyroid, wound etc

Remarks:

Name: _____
Organisation: _____
Date:

A3.7 *In vitro* bioassay measurement report

Unique Person Code:

Forenames: _____ Sex: M ☐ F ☐

Family Name:_____

Age: _____

Sample Bottle Number(s): _____
Radionuclide:_____

Has a correction for decay been made: Yes ☐ No ☐
If yes, reference date used: day/month/year (dd/mm/yy) ____/____/___

Urine measurement:
Collection dates and times:
Start: (dd/mm/yy, HH:MM) ____/____/___ __:__
End : (dd/mm/yy, HH:MM) ____/____/___ __:__
Total sample volume (l): _____
Normalisation method: time / volume / creatinine
Analysis Method _____

Date of Analysis	Activity, Bq ± standard uncertainty	Activity Bq/day ± standard uncertainty

Faeces measurement:
Collection dates and times:
Start: (dd/mm/yy, HH:MM) ____/____/___ __:__
End : (dd/mm/yy, HH:MM) ____/____/___ __:__
Analysis Method _____

Date of Analysis	Sample Mass, g	Activity, Bq ± standard uncertainty	Activity, Bq/day ± standard uncertainty

Other biological samples:
Sample Type: blood / nasal swab / nose blow / mouth swab / hair / excised tissue
Other (give details): _____
Collection date and time: (dd/mm/yy, HH:MM) ____/____/___ __:__
Analysis Method _____

Date of Analysis	Mass, g or Volume, l		Activity Concentration, Bq/g or Bq/l

Remarks:

Name:_____
Organisation:_____
Date: _____

A3.8 Individual dose assessment report form

Unique Person Code:

Forenames: _____ Sex: M ☐ F ☐

Family Name: _____
Age: _____ Weight [kg]: _____

Date of exposure (dd/mm/yy): _____/_____/_____Time of exposure (HH:MM): __:__

Intake pathway: Inhalation ☐ Ingestion ☐ Skin absorption ☐ Wound ☐

Chemical Form:_____ Absorption Type _____

Physical Form _____ Particle Size [µm] _____

Details of any treatment:_____

Date of measurement (dd/mm/yy): _____/_____/_____

Time of measurement: (HH:MM): ___:___

Date of sampling (dd/mm/yy): _____/_____/_____

Calculated Intake and Committed Dose Assessment

Radionuclide	Type of measurement*	Measured Value [Bq / Bq/d]	Intake [Bq]	Dosimetry Model	Committed Effective Dose [mSv]

* indicate if *in vitro* (urine, faeces etc.) or *in vivo* (whole body, lung etc.)

Calculated RBE-Weighted Absorbed Dose (if assessed)

Radionuclide	Organ or tissue	Time after intake, days	RBE- Weighted absorbed dose [Gy-Eq]*

* Integrated over 30 days after intake

Remarks:

Name: _____
Organisation: _____
Date:

A3.9 Emergency personnel dose follow up form

Person ID Code : ☐☐☐☐☐☐☐☐☐☐☐☐☐☐ Sex: ☐ M ☐ F

First Name : _____ Family name: _____

Stable iodine taken: ☐ Yes ☐ No If yes, date of administration _____ Time _____

Information on the performed actions and occupancy times for the dose assessment

Date and time	Actions done/ Working area	Dose rate at the working area (mSv/h)	Occupancy time in working area (h)	Dose (mSv) (Present action)	Cumulated dose (mSv) (All actions)	Surveyed by

A3.10 Example report letter to members of the public for measurements less than the method detection limit

Report No
Subject name
Date of Birth
Subject address
Unique Person Code

Date of report

RESULTS OF MEASUREMENT FOR *[Insert name of radionuclide]* FOLLOWING *[Insert name of incident]* INCIDENT

Dear *[insert name of subject]*

I am writing to confirm that your test result has shown that you have not been exposed to *[insert name of radionuclide]* as a result of this incident. *[Alternative text: I am writing to confirm that your test result has shown that any contamination in your body is below the level that can be reliably detected].*

Measurement result

The amount of *[insert name of radionuclide]* excreted in your urine was less than XX Bq/day[1]. *[Insert similar statements for other measurement types].* This level suggests you have not had any intake of *[insert name of radionuclide]* as a result of the incident.

Further advice

I enclose a question and answer fact sheet. If you have any other concerns, please either contact your family doctor (take this letter with you) or the Call Centre on *[Insert contact details (area code-number)].*

For the purposes of long term follow up, your details will be kept on a confidential register at the *[Insert name of national institute].* If you do not wish your details to be stored please let us know on the above telephone number.

Yours sincerely

[Insert name of person authorised to issue reports]
[Insert job title of person authorised to issue reports]

[1] Bq = Becquerel, unit of radioactivity.

A3.11 Example report letter for assessed doses less than 1 mSv

Report No
Subject name
Date of Birth
Subject address
Unique Person Code

Date of report

Dear .....

RESULTS OF MEASUREMENT FOR *[Insert name of radionuclide]* FOLLOWING *[Insert name of incident]* INCIDENT

I am writing to confirm that your urine test result *[insert similar statement for other measurement types]* has shown that you have been exposed to a very low level of *[insert name of radionuclide]*.

Measurement result
The amount of [*insert name of radionuclide]* excreted in your urine was XX Bq/day[1] *[insert similar statement for other measurement types]*. This suggests you have come into contact with [*insert name of radionuclide]* during this incident.

Estimate of dose
The radiation dose you have received as a result of this intake is less than 1 mSv[2].

Conclusion
This level of dose is regarded as insignificant. For comparison, the average annual dose received by a typical resident from all sources of natural radiation is *[insert appropriate value]* mSv per year. Thus, there is an extremely small additional radiation exposure as a result of the incident. This will not cause any short-term health effects and is extremely unlikely to give rise to any long-term health effects.

I enclose a question and answer fact sheet. If you have any concerns, please either contact your family doctor (take this form with you) or the Call Centre on [Insert contact details *(area code-number)*].

For the purposes of long term follow up, your details will be kept on a confidential register at the [Insert name of national institute]. If you do not wish your details to be stored please let us know on the above telephone number.

Yours sincerely

[Insert name of person authorised to issue reports]
[Insert job title of person authorised to issue reports]

[1] Bq = Becquerel, unit of radioactivity.
[2] mSv = millisievert, one thousandth of a sievert, a unit of radiation dose.

A3.12 Example report letter for assessed doses greater than 1 mSv and less than the lower action level (maximum 20 mSv)

Report No
Subject name
Date of Birth
Subject address
Unique Person Code

Date of Report

Dear .....

RESULTS OF MEASUREMENT FOR *[Insert name of radionuclide]* FOLLOWING *[Insert name of incident]* INCIDENT

I am writing to confirm your test result has shown that you have been exposed to *[insert name of radionuclide]*.

Measurement result

The amount of *[insert name of radionuclide]* excreted in your urine was XX Bq/day[1] *[Insert similar statements for other measurement types]*. This suggests you have come into contact with radioactive material as a result of this incident.

Estimate of dose

The radiation dose you have received as a result of this intake is *[insert value for best estimate of dose]* mSv[2].

Conclusion

This level of dose is regarded as low. For comparison, the average annual dose received by a typical resident from all sources of natural radiation is *[insert appropriate value]* mSv per year. *[Other dose comparisons may be used, such as dose from a transatlantic flight or dose from a chest X-ray or a CT scan]*. Thus, there is an additional radiation exposure as a result of the incident. This will not cause any short term health effects and is unlikely to give rise to any long-term health effects.

I enclose a question and answer fact sheet. If you have any concerns, please either contact your family doctor (take this form with you) or the Call Centre on [Insert contact details *(area code-number)*].

For the purposes of long term follow up, your details will be kept on a confidential register at the [Insert name of national institute]. If you do not wish your details to be stored please let us know on the above telephone number.

Yours sincerely

[Insert name of person authorised to issue reports]
[Insert job title of person authorised to issue reports]

[1] Bq = Becquerel, unit of radioactivity.
[2] mSv = millisievert, one thousandth of a sievert, a unit of radiation dose.

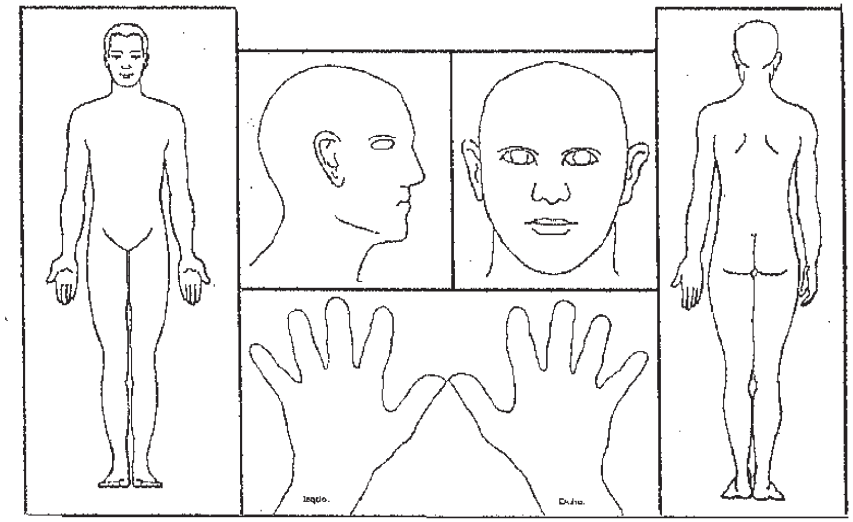
A3.13 Medical information form

Incident information (As this information is the same for all casualties, this section can be copied and attached to the medical record of the other patients)
Accident location:
Date and time of the incident:
Number of persons involved: ☐ < 10 ☐ 10-50 ☐ 50-100 ☐ 100-500 ☐ >500
General incident description:
Source of irradiation: ☐ Unknown ☐ Known If known, specify:
Additional comments:

Patient code:		**Date and time of admission:**
General Patient Data		
Patient name (last, first):		
Current local full address: Permanent full address:		
Telephone:	Fax:	E-mail:
Date of birth:		Sex: ☐ Male ☐ Female

Information on the person completing this form
Name (last, first):
Place of work (i.e. department/service):
Status: ☐ Physician ☐ Health personnel ☐ Other:

Personal exposure information
Actions at the time of the accident:
Individual incident description: (include location, time, duration and use of any personal protective equipment)
SITES OF INJURY, TRAUMA OR CONTAMINATION ***(identify type of lesion)***



Use the code:
1 - Thermal burn
2 - Wound
3 - Erythema
4 - Contamination
5 - Other injury/trauma (specify)

Dose Estimates (fill in as soon as results are available)			
Evaluation of average Total Body Irradiation (TBI):	Date:	Method:	Dose (Gy):
Evaluation of local doses:	Date:	Method:	Dose (Gy):
Other:	Date:	Method:	Dose (Gy):
Kind of radiation: ☐ α-particles ☐ β-emitters ☐ γ-source ☐ X-rays Other:			
Known/suspected: ☐ Contamination ☐ Incorporation			
If the patient had a dosemeter:			
Dosemeter number:			
Dosemeter readings:			
Body location of the dosemeter:			

Previous history	
Information of special interest concerning ARS (uk = unknown)	
Central nervous system (CNS)	
Psychiatric disorders:	☐ uk ☐ no ☐ yes, if yes, please specify:
Neurological disorders:	☐ uk ☐ no ☐ yes, if yes, please specify:
Neurovascular disorders:	☐ uk ☐ no ☐ yes, if yes, please specify:
Malignancies:	☐ uk ☐ no ☐ yes, if yes, please specify:
Others:	☐ uk ☐ no ☐ yes, if yes, please specify:
Haematopoietic system	
Leukaemia:	☐ uk ☐ no ☐ yes, if yes, please specify:
Myelodysplasia:	☐ uk ☐ no ☐ yes, if yes, please specify:
Other malignancies:	☐ uk ☐ no ☐ yes, if yes, please specify:
Others:	☐ uk ☐ no ☐ yes, if yes, please specify:
Skin	
Scars:	☐ uk ☐ no ☐ yes, if yes, please specify:
Rash:	☐ uk ☐ no ☐ yes, if yes, please specify:
Mycotic diseases:	☐ uk ☐ no ☐ yes, if yes, please specify:
Allergic diseases:	☐ uk ☐ no ☐ yes, if yes, please specify:
Malignancies:	☐ uk ☐ no ☐ yes, if yes, please specify:
Others:	☐ uk ☐ no ☐ yes, if yes, please specify:
Gastro-intestinal tract (GIT)	
Related diseases:	☐ uk ☐ no ☐ yes, if yes, please specify:
Malignancies:	☐ uk ☐ no ☐ yes, if yes, please specify:
Others:	☐ uk ☐ no ☐ yes, if yes, please specify:

Additional health information (including date of first diagnosis)
Other organ systems
Lung: Heart: Vascular system: Liver: Bone and skeleton: Endocrine system: Eyes: Others:
Pregnancy: ☐ Unknown ☐ No ☐ Yes Date of the beginning of the last menstruation:
Malignancies
Allergies
Past hospitalisations
Medical exposure to ionising radiation: ☐ Diagnostic radiology ☐ Radiotherapy ☐ Interventional radiology ☐ Nuclear medicine
Habits
Tobacco: Alcohol: Others:
Former occupation
Other relevant information:

Family History (questions of special interest)		
Number of siblings:	Sisters:	Brothers:
Number of children:	Daughters:	Sons:
Cardiovascular diseases:	☐ no ☐ yes: ☐ mother ☐ father ☐ brother ☐ sister ☐ other If yes, please specify:	
Malignancies:	☐ no ☐ yes: ☐ mother ☐ father ☐ brother ☐ sister ☐ other If yes, please specify:	
Metabolic disorders:	☐ no ☐ yes: ☐ mother ☐ father ☐ brother ☐ sister ☐ other If yes, please specify:	
Haematological disorders:	☐ no ☐ yes: ☐ mother ☐ father ☐ brother ☐ sister ☐ other If yes, please specify:	
Others:	☐ no ☐ yes: ☐ mother ☐ father ☐ brother ☐ sister ☐ other If yes, please specify:	
Medication		
Past medication:		
Current medication:		
Post exposure		
Chief complaints and timing of symptoms on admission (more detailed description below):		
Date/time	Complaint	Description

Vital signs on admission		
Date/time	Sign	Description
	Blood pressure	
	Heart rate	
	Respiratory rate	
	Temperature	
	Others	

Radiation related health impairments of other organ systems		
	Description	Consultation
Lung		no yes
Heart		no yes
Eyes		no yes
Liver		no yes
Bone and skeleton		no yes
Endocrine system		no yes
Lymph nodes		no yes
Mucous membranes		no yes
Salivary glands		no yes
Others		no yes

Measures taken at the hospital
Undressing ☐ no ☐ yes
Decontamination ☐ no ☐ yes If yes, provide details:
Decorporation: ☐ no ☐ yes If yes, provide details:
Blood samples for cytogenetic dosimetry taken: ☐ no ☐ yes
Blood samples for HLA typing taken: ☐ no ☐ yes
Sample/s for radioactivity measurement taken: ☐ no ☐ yes If yes, provide details as follows: ☐ Blood ☐ Nose ☐ Mouth ☐ Wound ☐ Urine ☐ Faeces ☐ Other (provide details)

Blood samples for blood cell count with full differential

Date	Time	Absolute lymphocyte count (per µl)	Absolute neutrophil count (per µl)	Absolute platelet count (per µl)

Patient ID :	Beginning of exposure :	Examiner :

Degree of severity according to METREPOL system as presented in Table J4

Neuro-vascular system (N)	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:
Nausea								
Vomiting								
Anorexia								
Fatigue syndrome								
Fever								
Headache								
Hypotension								
Neurological deficits								
Cognitive deficits								
Maximum								
Grading N								

Degree of severity according to METREPOL system as presented in Table J5								
Haema-topoietic system (H)	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:
Lymphocyte changes								
Granulocyte changes								
Thrombocyte changes								
Infection								
Blood loss								
Maximum								
Grading H								

Degree of severity according to METREPOL system as presented in Table J6								
Cutaneous system (C)	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:
Erythema								
Sensation/ itching								
Swelling/ oedema								
Blistering								
Desquamation								
Ulcer/ necrosis								
Hair loss								

Onycholysis								
Maximun								
Grading C								

Degree of severity according to METREPOL system as presented in Table J7								
Gastro-intestinal system (G)	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:	Date: Time:
Frequency (stool)								
Consistency (stool)								
Mucosal loss/day (stool)								
Bleeding/day (stool)								
Abdominal cramps/pain								
Maximum								
Grading G								
Highest grading code								

A3.14 Information for family doctors in the event of an incident involving radiation

Information for family doctors in the event of an incident involving radiation

- The attached information provides a brief description of the event. Although a number of people were sent to the hospital according to their clinical condition, you may receive symptomatic patients, concerned people or worried well.

- During consultation, try to identify signs and symptoms which might be attributable to radiation exposure, such as:
  - Nausea
  - Vomiting
  - Diarrhoea

- The following signs may be indicative of radiation exposure, particularly if the patient does not recall being "burned" and there is no apparent cause:
  - Erythema
  - Swelling/oedema
  - Blistering
  - Desquamation
  - Skin ulcer
  - Acute hair loss

- If your patient exhibits any of these signs/symptoms, perform a blood cell count with full differential. Radiation exposure will be especially suspected if any of the aforementioned clinical signs/symptoms are associated with lymphocytopenia, granulocytopenia and/or thrombocytopenia.

- In case that one or more of these signs/symptoms are present:
  - ask your patient about her/his whereabouts with respect to the site of the event and try to obtain an estimation of the time duration spent there;
  - contact the following emergency response hotline number *(area code) – number* (inform specifically if the patient is a child, pregnant woman or a breastfeeding mother); and
  - repeat this procedure for each patient exhibiting similar signs/symptoms.

- If your patient is pregnant between the 8th and 25th gestational week and refers to having been in the proximity of the site of the event, contact the following emergency response hotline number *(area code) – number*.

- In order to avoid overwhelming hospitals, refer patients to peripheral health care centres where they will be assigned to the appropriate medical facility, as necessary.
- Inform your patient about the availability of psychological support at these centres.

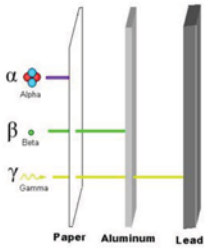
Photos: courtesy of IAEA (left: IAEA, 2000b; right: IAEA, 2002a).

A3.15 Information to people who have been found to be contaminated with radioactive material

Information to people who have been found to be contaminated with radioactive material

Radiation and radioactivity

We cannot eliminate radiation from our environment. We can, however, reduce our risks by controlling our exposure to it. Understanding radiation and radioactivity will help you make informed decisions about your exposure.



What is ionising radiation?

Ionising radiation is energy that travels in the form of waves (gamma or X-rays) or high speed particles (alpha and beta), and its penetrating properties are depicted on the left.

What is radioactivity?

Radioactive material spontaneously undergoes a change while sending out high energy radiation as particles or waves

How are people exposed to radiation?

When we hear the words 'radiation exposure', we generally think of radiation from a source beaming out and striking the exterior of a body. However, radioactive particles can also become lodged inside the body and expose internal organs as the radionuclides decay. As a result, health physicists consider not only the type of radiation emitted from a source, but also the routes by which people are likely to come into contact with it. There are three main routes of exposure or exposure pathways:

- **Inhalation**. Exposure by the inhalation pathway occurs when people breathe radioactive materials into the lungs. The main concerns are radioactively contaminated dust, smoke, or gaseous radionuclides.
- **Ingestion**. Exposure by the ingestion pathway occurs when someone swallows radioactive materials.
- **External exposure**. Exposure to radioactive sources/ material outside your body. The level of concern for exposure to different kinds of radiation varies from "limited" for alpha particles since they cannot penetrate the outer layer of skin (but if you have any open wounds you may be at risk); "intermediate" concern for beta particles which can, in some cases, burn the skin or damage eyes. Greatest concern is for gamma radiation since gamma rays can travel long distances and penetrate the body.

What happens to ingested radioactive materials?

Ingested radionuclides can expose the entire digestive system. Some radionuclides can also be absorbed and expose the kidneys and other organs, as well as the bones. Radionuclides that are eliminated by the body fairly quickly are of limited concern.

What happens to inhaled radioactive materials?

Radioactive particles can lodge in the lungs and remain for a long time. As long as it remains and continues to decay, the exposure continues. For radionuclides that decay slowly, the exposure continues over a very long time. Inhalation is of most concern for radionuclides that are alpha or beta particle emitters.

A3.16 Information to people who might have been exposed to radiation/radioactive material

You may have been exposed to radioactive material
We need to monitor you

Photos: courtesy of Mark V. Carr.

Detection of external contamination

If external contamination is detected, there may be a need for decontamination. Decontamination should be carried out as soon as possible, but does not require the same immediacy as with chemical or biological contamination.

If only low levels of external contamination are detected, you may be instructed to return home and take decontamination measures. If you are instructed to do so, you should:

- Remove clothing and seal in a plastic bag. Bags of clothing should be retained until you are provided with further information on disposal or laundering requirements.
- Shower or bath thoroughly, but gently, washing both skin and hair. Hair conditioner should not be used as this may bind material to the hair.
- Do not eat, drink or smoke until washing is complete.

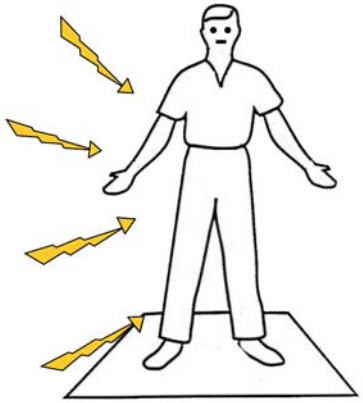
Detection of internal contamination

If you are found to have radioactive material inside your body, you may be issued with medication to assist in the removal of material from your body.

Information will be provided to you should you require internal decontamination measures.

You may also be asked to provide samples of urine to assist in monitoring the elimination of material from your body.

You might have been exposed to radiation



and/or

External irradiation
You may have been exposed to external radiation

Internal and/or external contamination
You may have radioactive material inside your body and/or on your clothing or skin.

Photo: courtesy of U.S. Air Force.

If external contamination is suspected, we may conduct precautionary decontamination measures

Stay calm

Decontamination does not need to be conducted immediately!

DO NOT EAT, DRINK or SMOKE until you have been decontaminated

A3.17 Examples of press releases

Contact Person:
Institution
Phone number:
Fax number:
Press release web:

Full Address

Institution logo

Press Release

Example Press Release for an Incident Involving the Discovery of a Radioactive Source in a Public Place

[Organisation name] confirms that the dangerous radioactive material was discovered at [specify]. According to the information received at this time, the material was discovered at [time and location]. Reports indicate that [any confirmed information on effects] and that [any initial measures] measures are being taken to protect [the public or specify as appropriate]. The [specify plan as appropriate] emergency plan has now been activated [and we have activated our public information centre].

The public is advised on the following:

- Those who may have been near to where the material was found within the past [specify time interval] and/or may have been near to it while it was being carried/shipped [specify details] should contact [specify] to be assessed and get instructions.
- People with health concerns are requested to go to [once available specify a location away from the local hospitals where primary health care will be provided] or consult their general practitioner.

Medical practitioners are advised of the possibility that patients may present with symptoms attributable to radiation exposure [e.g. nausea, vomiting, diarrhoea, skin burns with no apparent cause]. If you believe you have information that may be helpful or questions please call [give a hotline number where a large number of calls will not interfere with the response].

We will be providing further information as soon as it becomes available. [Provide details on timing of any updates or briefings]. The next [briefing/update] will take place at [location and/or time].

For release time, Date

Contact Person:
Institution
Phone number:
Fax number:
Press release web:

Full Address

Institution logo

Press Release

Example Press Release for an Incident Involving the Release of Radioactive Material in a Public Place

[Organisation name] confirms that there is an event possibly involving radioactive material [nature of event]. According to the information received at this time, the [event] occurred at [time and location]. Reports indicate that [any confirmed information on the event] and that [any initial measures] measures are being taken to protect [the public, responders, food]. The [specify plan as appropriate] emergency plan has now been activated [and we have activated our public information centre].

The public is advised on the following:

- Do not handle any possible radioactive item [e.g. fragment from a bomb or any item picked up at the scene].
- Those who left the scene without being assessed by the [specify] should change their clothing, shower (if possible), wash hands before eating and go to [specify] to be assessed and get instructions or wait for instructions.

[If an airborne release is suspected (specify, depending on scenario)] the public within about 1 km of [specify local description – roads, districts – that will be understandable to the public] are advised on the following:

- Remain inside until [specify when any actual or possible release will be over];
- Do not eat or drink anything that may have been contaminated (e.g. vegetables grown outside or rainwater) until informed otherwise;
- Make sure that children are not playing on the ground;
- Wash hands before eating;
- Do not go to the scene to volunteer or to help. If assistance is needed announcements will be made.

If you have a health concern go to [once available specify a location away from the local hospital where monitoring will be performed and questions answered]. If you have any questions please call [give a hot line number where large number of calls will not interfere with the response].

We will be providing further information as soon as it becomes available. The next [briefing/update] will take place at [location and/or time].

For release time, Date

Annex 4: Allocation of roles

The following is a list of the roles and teams that are needed to respond to a radiological incident. The availability of staff to perform these roles will need to be confirmed as part of the planning. All staff will need appropriate training. Roles which exist under normal circumstances are not described in detail.

Tactical Incident Command (TIC)

The function of the TIC includes:

- Assessment of the situation;
- Ensure people are rescued;
- Ensure people are evacuated from hazardous areas;
- Ensure safety and security perimeters are established;
- Ensure entry to hazardous areas is limited to essential staff;
- Ensure personnel protection guidelines are followed;
- Ensure conventional hazards (such as fire) are dealt with;
- Request deployment of other teams, such as monitoring and decontamination;
- Ensure injured are taken to hospital and receiving hospitals are informed; and
- Ensure zones described in chapter E are established as required.

The TIC is in overall charge of all personnel operating at the site of the incident. It is likely that the most senior member of the First Responder Teams will assume the role of leading the TIC. The TIC could consist of several people, including a medical coordinator and a radiological liaison, if appropriate. The TIC reports to the Strategic Command.

Strategic Command

The Strategic Command is in overall charge of the response to the incident, but is not present at the scene. It will set priorities and ensure protection of the public and emergency workers. The Strategic Command is likely to have advisory teams, such as a team to determine probable health effects. The Strategic Command is likely to be headed by a senior member of the Security Forces (e.g. Police) or a senior member of local government. The

Strategic Command will report to national or local government.

The function of the Strategic Command includes:

- Ensure all appropriate resources are activated;
- Establish communication with TIC at the scene;
- Approve press releases;
- Approve public information announcements;
- Appoint teams of advisors including a press spokesperson;
- Ensure radiological and non radiological situations are assessed based on information received from the TIC; and
- Provide information to central Government.

First Responders

The function of the First Responders is to establish the Red and Yellow Zones, to perform life saving actions, to apply first aid to affected people, to carry out trauma triage, and to perform other actions that are necessary for the safety of the public and rescue teams. The term First Responders includes Police, Ambulance Service and Fire Service.

Security Personnel

The function of Security Personnel at the scene, is to guard the boundaries of the Red and Yellow Zones so that the first responders can perform their actions and will not be hindered by members of the public. Security Personnel would normally be police staff, but could include military or civil protection staff at the scene.

At the hospital, the function of the Security Personnel would be to arrange for arrival of patients (clear necessary areas from other patients and public, initiate access control, plan for radioactive waste disposal etc.) as described in chapter J. This function would normally be covered by the existing hospital security staff.

Ambulance Team

The function of the Ambulance Team is to supply first aid and take casualties to the hospital.

Medical Team

The function of the Medical Team is to carry out trauma triage at the scene and to carry out medical interviews of people who may have symptoms of radiation exposure in support of radiological triage. In addition to usual medical training, these staff will need specific training for incidents involving radioactivity. The Medical Team will report to the TIC.

Environmental Monitoring Team

The function of the Environmental Monitoring Team is to carry out environmental monitoring at the site of the incident to assess radiation and contamination levels. The staff in these teams will be familiar with a wide range of monitoring techniques and have available instruments to perform the monitoring tasks described in Chapter E. They will also have access to Personal Protection Equipment (PPE) and have received training in responding to a deliberate release. The Environmental Monitoring Team will report to the TIC.

Radiological Triage Team

The function of the Radiological Triage Team is to prioritise people for medical assessment, radiation measurements and decontamination procedures, using the techniques described in Chapter F. The information needed for the triage process may be recorded by others such as a Record Team using questionnaires, or from screening measurements. The Radiological Triage Team would need specific training in how to use the procedures described in this Handbook. It is probable that the Radiological Triage Team would be staffed by national radiation protection organisations supported by public health professions (e.g. medical doctors and nurses). The Radiological Triage Team will report to the TIC.

Decontamination Team

The function of the Decontamination Team will be to supervise and assist people with decontamination procedures. For decontamination done very soon after the incident, this role may be performed by the Fire Service. For decontamination procedures carried out at locations outside of the security zone this role is likely to be fulfilled by Civil Protection/Army personnel/ Nurses. Training will depend on the role. Staff that would operate specialist mass decontamination units will require specific training. For decontamination at locations away from the incident, only simple

techniques are needed so personnel are unlikely to require specific training. The Decontamination Team will report to the TIC.

People Monitoring Team

The function of the People Monitoring Team will be to monitor people for external contamination and possibly also internal contamination [Chapter F – initial monitoring; Chapter H – later monitoring]. The People Monitoring Team will report to the TIC if working in the People Processing Area within the Security Perimeter (Yellow Zone) or alternatively indirectly to the Strategic Command. The People Monitoring Team is likely to be staffed by national radiation protection organisations. The team members must be familiar with monitoring techniques and have access to PPE. As access to the Red Zone is not foreseen, specific training for working in a strongly contaminated environment would not be required.

Dose Assessment Team

The function of the Dose Assessment Team is to calculate doses from external irradiation and internal or/and external contamination for response staff and members of the public [Chapter H]. The team members would most probably be specialist staff from national radiation protection organisations. The Dose Assessment Team would need to communicate with the Environmental Monitoring and People Monitoring Teams to obtain the information needed for dose assessments. The Dose Assessment Team could comprise one of the advisory groups to the Strategic Commander.

Records Team

The function of the Records Team is to provide administrative support to other teams. It is likely that this function is not always performed as a separate team, but that administrative personnel is added to the other teams in the field. In the response to an incident there will be a need for recording the different actions taken and results gained. Records will be required for:

- Details of the movements and cumulative doses to monitoring staff deployed in hazardous area;
- The results of environmental monitoring;
- Subject questionnaire forms to register people who have been affected by the incident and as an aid to radiological triage; and
- The results of monitoring people for external and internal contamination.

The Records Team will report to the leader of the relevant team to whom they are providing assistance.

Emergency Medical Manager

The Emergency Medical Manager is a senior member of the receiving hospital's staff who is responsible for activating the hospital's emergency plan, responsible for allocating tasks and ensuring that specialist teams are available. It is likely that specialist training will be needed for this role.

Hospital Emergency Team

The Hospital Emergency Team consists of doctors and nurses who are designated to deal with emergencies.

Pathology Department

In addition to normal duties, this department will be responsible for dealing with contaminated corpses. Training for this duty will be required.

Radiation Protection Officer

Some countries have designated Radiation Protection Officers at the hospitals responsible for all radiation protection issues. It would be pertinent to involve such officers in radiation emergency work at the hospital.

Health/Medical Physicists

In addition to their normal role in hospitals, health/medical physicists may be required for monitoring of people at the hospital due to their knowledge of working with radiation. Some training would be required to fulfil this extra task.

Annex 5: Interpretation of clinical signs and symptoms

The time from exposure to onset of vomiting is the most important information in making a prognosis and an estimate of the dose received. The frequency and severity of nausea and diarrhoea is also important information (Goans and Waselenko, 2005; Blakely et al, 2005). Table A5.1 summarises the time of onset of vomiting and diarrhoea, and the likelihood of observing these symptoms, for different levels of severity of prognosis (Mild – Moderate – Severe – Very Severe – Lethal) and estimated acute whole body exposure doses (1 – 2 Gy, 2 – 4 Gy, 4 – 6 Gy, 6 – 8 Gy, > 8 Gy).

The following guidelines should also be taken into account when making decisions on hospital referrals.

- 'Those patients experiencing emesis (i.e. vomiting) < 4 h post-incident should be triaged to professional medical care while those with time to emesis (TE) > 4 h could be sent home initially or instructed to receive delayed medical attention' (Goans and Waselenko et al, 2005).
- Those with TE > 4 h ' … should have medical follow up within the next several days' (Mettler, 2005).
- 'For TE < 1 h post-event, the prognosis is much more serious. Patients…..will generally require extensive and prolonged medical intervention and an ultimately fatal outcome will occur in many instances' (Goans and Waselenko et al, 2005).

Medical treatment issues are addressed in Section J.5.

Table A5.1 Prodromal phase of acute radiation syndrome. Reproduced courtesy of IAEA (IAEA Safety report series 2, 1998).

Table VIII Prodromal phase of acute radiation syndrome

Symptoms and medical response	ARS degree and the approximate dose of acute WBE (Gy)				
	Mild (1-2 Gy)	Moderate (2-4 Gy)	Severe (4-6 Gy)	Very severe (6-8 Gy)	Lethal[a] (>8 Gy)
Vomiting					
Onset	2 h after exposure of later	1-2 h after exposure	Earlier than 1 h after exposure	Earlier than 30 min after exposure	Earlier than 10 min after exposure
% of incidence	10-50	70-90	100	100	100
Diarrhoea	None	None	Mild	Heavy	Heavy
Onset	-	-	3-8 h	1-3 h	Within minutes of 1 h
% of incidence	-	-	< 10	> 10	Almost 100
Headache	Slight	Mild	Moderate	Severe	Severe
Onset	-	-	4-24 h	3-4 h	1-2 h
% of incidence	-	-	50	80	80-90
Consciousness	Unaffected	Unaffected	Unaffected	May be altered	Unconsciousness (may last seconds/minutes)
Onset	-	-	-	-	Seconds/minutes
% of incidence	-	-	-	-	100 (at > 50 Gy)
Body temperature	Normal	Increased	Fever	High fever	High fever
Onset	-	1-3 h	1-2 h	< 1 h	< 1 h
% of incidence	-	10-80	80-100	100	100
Medical response	Outpatient observation	Observation in general hospital, treatment in specialized hospital if needed	Treatment in specialized hospital	Treatment in specialized hospital	Palliative treatment (symptomatic only)

[a]With appropriate supportive therapy individuals may survive whole body doses as high as 12 Gy [36].

Therapeutical management
according to the European consensus conference*

Beyond the first 48 hrs, a second patient scoring is done by organs (Neurovascular, Hemopoesis, Cutaneous, Gut) according to the METREPOL document for therapeutical management and Multiple Organ Failure (MOF) prediction.**

Cytokines

Score I: Monitoring. No cytokine

- Outpatient clinical monitoring.
- Blood count: - every day for 6 days,
  - then once a week for 2 months.

Score II: Cytokines (curative)

- **G-CSF+ KGF should be used as early as possible for 14-21 days. TPO and agonists, EPO and stem cell factor questionable.**
- Symptomatic treatment of gastrointestinal damage.
- If severe aplasia → Protected environment.
- Accidental radiation exposure is generally heterogeneous. Some under-exposed/protected regions of bone marrow can give rise to endogenous hematopoietic recovery.

Score III: Cytokines (until reappraisal of score)

- Palliative/Symptomatic treatment.
- Re-evaluation during the first week based on laboratory or clinical symptoms revealing irreversible organ damage or multi organ dysfunction.

All blood products should be irradiated

Severe radiological skin lesions have a peculiar torpid evolution and require specialist treatment.

* N.C. Gorin *et al.*, Consensus conference on European preparedness for haematological and other medical management of mass radiation accidents, *Ann Hematol*, 85 : 671- 679, 2006.

** T.M. Fliedner *et al.*, Medical Management of Radiation Accidents – Manual of the acute radiation syndrome, published by BIR, 2001.

European group for Blood Marrow Transplantation.

Ulm University - Germany.

IRSN Institut de Radioprotection et de Sûreté Nucléaire - France.

Hematopoietic stem cell (HSC) transplantation

Background

- HSC transplantation is not an emergency.
- It is crucial to avoid GVHD in order not to compromise an endogenous recovery.
- If severe aplasia persists under cytokines for more than 14 days, the possibility of an hematopoietic stem cell (HSC) transplantation is discussed.

Criteria to transplant

- Severe marrow aplasia persisting 14 - 21 days.
- No residual hematopoiesis.
- No irreversible organ damage (GI tract, lungs...).

Graft

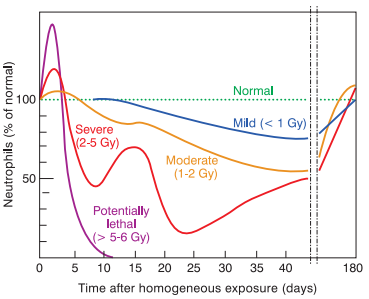
- **Type of graft:**
  - Bone marrow.
  - Peripheral blood HSC (depleted or not).
  - Cord blood.
- **Donor in the following order of priority:**
  - HLA-identical sibling or 7/8 matched.
  - HLA-identical unrelated donor or 9/10 matched.
  - Cord blood > 4/6 matched.
- **Doses of cells to be grafted:**
  At least: - $2x10^6$ CD34 cells.kg^{-1} (peripheral blood);
  - $2x10^8$ nucleated cells.kg^{-1} (bone marrow);
  - $3x10^7$ nucleated cells (cord blood).

Conditioning and GVHD prevention

- **Non myelotoxic conditioning:**
  - Fludarabine (30 $mg.m^{-2}.d^{-1}$ for 3 days) ± anti-lymphocyte globulins.
- **GVHD prevention:**
  - No Methotrexate.

European approach for the medical management of mass radiation exposure

EBMT IRSN



M. Akashi, B. Allenet-Le Page, D. Blaise, JF. Bottollier-Depois, A. Bushmanov, JM. Cosset, T. de Revel, T. Fliedner, F. Frassoni, A. Ganser, MH. Gaugler, NC. Gorin, P. Gourmelon, N. Griffiths, D. Lloyd, V. Meineke, D. Niederwieser, A. Nikiforov, R. Powles, AR. Oliveira, I. Resnick, G. Seitz, J.Sierra, B. Sirohi and L. Stenke.

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April 2007

Figure A5.1. European approach for the medical management of mass radiation exposure. Reproduced from EBMT, 2007, courtesy of authors. http://www.ebmt.org/7directory/committees/nuclear%20accident%20docs/Pocket_guide.pdf.

The first 48 hours

Life-threatening wounds and burns should be treated first
Irradiation is not contamination – An irradiated person is not a source of radiation – In case of additional contamination, decontamination comes first

Beware of Multiple Organ Failure (MOF)

The severity of prodromal clinical features is of major importance.

- Extensive and immediate erythema.
- Early Transient Incapacitation Syndrome (temporary loss of consciousness).
- High fever.
- Hypotension.
- Immediate diarrhoea.

Physical dosimetry

- Inquiry: circumstances of the accident, source characteristics, source-victim geometry, duration of exposure, daily dose rate, shielding, homogeneous/ heterogeneous irradiation.
- Labelling and storage of personal belongings and clothes, biological material (hair, nails).

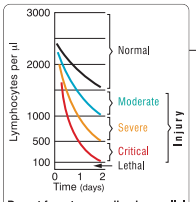
Urgent sampling

- Blood cell counts (+ differentials) every 4-8 hours for the 1st 24 hours, 12-24 h after.
- Chromosome abberations on blood lymphocytes (biodosimetry) (15 ml + heparin).
- Red cell group typing.
- Store serum and cells or DNA for further analyses including HLA typing.
- Standard biochemistry + amylasemia.
- Blood (20 ml) to measure ^{24}Na if exposure to neutrons.
- Urine and faeces if radionuclide contamination is suspected.

Primary scoring

Record all clinical symptoms on a date and hour-stamped chart

	Score I	Score II	Score III
Average delay before symptoms appear	Less than 12 hours	Less than 5 hours	Less than 30 minutes
Cutaneous erythema	0	+/-	+++; before 3rd hour
Asthenia	+	++	+++
Nausea	+	+++	(-)
Vomiting per 24 hrs	Maximum 1	1 to 10	Above 10; intractable
Diarrhea / Number of stools per 24 hrs	Maximum 2 - 3; bulky	2 - 9; soft	Above 10; watery
Abdominal pain	Minimal	intense	Excruciating
Headaches	0	++	Excruciating; Signs of intra-cranial HT
Temperature	Below 38°C	38 - 40°C	Above 40°C
Blood pressure	Normal	Normal - Possible temporary decrease	Systolic below 80
Temporary loss of consciousness	0	0	+ / Coma



Do not forget reccording in parallel neutrophils and platelets

Depletion of blood lymphocytes

	Score I	Score II	Score III
At 24 hours	Above 1 500 / µl	Below 1 500 / µl	Below 500 / µl
At 48 hours	Above 1 500 / µl	Below 1 500 / µl	Below 100 / µl
	Outpatient monitoring	**Hospitalisation for curative treatment**	**Hospitalisation (MOF predicted)**

Warning: the symptoms and values indicated above are reliable only in case the whole body or large parts of the body have been externally exposed to a high radiation dose delivered within few minutes or few hours. Fill and fax MED A (radiation accident) to : (+33)1 40 46 96 07

Annex 6: Specifying a monitoring strategy for internal contamination

Choice of monitoring method

In most cases, assessment of intakes of radionuclides may be achieved by body activity measurements (direct bioassay), urine monitoring or faecal monitoring (indirect bioassay), or a combination of these techniques. The choice of measurement technique will be determined by a number of factors including:

- The radiation emitted by the radionuclide and its progeny;
- The half-life of the radionuclide;
- The respiratory tract deposition characteristics of the aerosol;
- The respiratory tract absorption characteristics of the material;
- The retention in the body or the excretion rate from the body as a function of the time between intake and measurement;
- Any preferential deposition in particular body organs after systemic uptake, and retention in those organs;
- Any significant differences between the biokinetic behaviour of a parent radionuclide and its progeny;
- The excretion pathway (i.e. urine, faeces); and
- The technical feasibility of the measurement.

For some radionuclides, only one measurement technique is feasible, e.g. urine monitoring for intakes of tritium. For radionuclides such as plutonium isotopes that present difficulties for both measurement and interpretation, a combination of techniques may have to be employed. If different methods of adequate sensitivity are available, the general order of preference in terms of accuracy of interpretation is:

1. Body activity measurements.
2. Urine analysis.
3. Faecal analysis.

These techniques are, however, complementary and not mutually exclusive.

IAEA Safety series 114, 1996, has given guidance on the direct measurement of body content of radionuclides. Advice has also been issued by ICRU Report, 69, 2003. Direct (*in vivo*) bioassay is likely to be the monitoring method of choice if the radionuclide is a high yield, high energy gamma emitter, unless the material is excreted rapidly from the body. The gamma radiation emitted by such radionuclides is strongly penetrating, and so is readily detected using scintillation or semiconductor detectors positioned close to the body. If the material is absorbed rapidly from the respiratory tract, and is then either distributed uniformly in body tissues (e.g. ^{137}Cs in most common chemical forms), or is distributed preferentially among a number of organs, then whole body monitoring should be chosen. If the material deposits preferentially in a single organ such as the thyroid (e.g. ^{125}I,^{131}I), then partial body monitoring of the relevant organ should be chosen. In the case of materials that are absorbed less rapidly from the respiratory tract (e.g. insoluble forms of ^{60}Co oxide), lung monitoring is preferable to whole body monitoring soon after the intake, as it gives a more accurate measure of lung deposition and retention than a whole body measurement.

Direct bioassay is also useful for some radionuclides that emit photons (X- or gamma-rays) at lower energies and/or with lower yields (e.g. ^{241}Am). However, in the extreme case of radionuclides that mainly emit X-rays below 25 keV with low yields (notably, the alpha-emitting isotopes of plutonium) direct bioassay cannot achieve the sensitivity required for radiological protection purposes.

If direct bioassay monitoring is available, it should be chosen in preference to indirect (*in vitro*) bioassay. Nevertheless, indirect bioassay does have important areas of application. For radionuclides that do not emit penetrating radiation with sufficient yields, (e.g. the pure beta emitter ^{90}Sr, the alpha-emitting isotopes of plutonium), indirect bioassay usually has to be chosen as the primary monitoring method. Urine monitoring provides a measure of systemic uptake to organs, and so is useful for materials that are absorbed relatively rapidly from the respiratory tract (i.e. materials that have absorption characteristics within the range defined by default types F and M).

Caution should be exercised in using urine monitoring for materials that are absorbed relatively slowly from the respiratory tract (i.e. “insoluble”

materials). In these circumstances, it is usually the lung dose that makes the greatest contribution to effective dose, and uncertainties or lack of knowledge of the absorption characteristics of the material can then result in significant errors in assessed dose.

For insoluble materials, significant improvements in sensitivity can be achieved by using faecal monitoring in preference to, or in addition to, urine monitoring. This arises because significant fractions of insoluble material deposited in both the extrathoracic airways and the lungs are cleared via the gastro-intestinal tract to faeces. Interpretation of faecal monitoring data needs to take account of a number of factors that are specific to the faecal excretion pathway. Excretion of faeces is of course a discrete process (even though it is usually modelled using first-order kinetics), and so it is advisable to sum the amounts excreted over a 3-day period to obtain a daily excretion rate. Although faecal excretion rates after an acute inhalation are typically highest in the 12 - 72 hour period post intake, they may be subject to the highest levels of intra- and inter-subject variability during this interval, making it advisable to extend the period for special monitoring to later times. Another important consideration that applies to both faecal and urine monitoring, is that many of the materials for which indirect bioassay is useful are naturally-occurring (e.g. uranium oxides). For such materials, it is necessary to quantify and take account of natural background excretion levels and their variability.

For some actinide compounds (uranium and elements with higher atomic number), individual monitoring by direct or indirect bioassay may not reliably quantify doses below a few mSv. This could be the case where the biokinetic behaviour of the material results in urine excretion rates that are so low that alpha spectrometry does not have adequate sensitivity, more sensitive mass spectrometric techniques for urine measurements are not available, and faecal monitoring is not feasible.

Annex 7: Later triage and monitoring

Introduction

The deliberate dispersal of radioactive aerosols into the public environment will require urgent decisions to be made on whether or not treatment for its removal from the body should be considered or implemented, or whether the public can be reassured that radiation doses are acceptably low. However, such decisions are likely to be difficult due to lack of information on the chemical form, solubility and particle size distribution of the aerosol, the biokinetic and retention characteristics of the radionuclide in the body and the likely efficacy of treatment for the chemical forms likely to be present.

A simple dose assessment tool is described that will simplify the decision making process. This approach is considered appropriate for rapid decisions on medical management or public reassurance when potentially large numbers of people are involved. It is not intended as a substitute for individual dose assessment, when several measurements may be made and where the results of investsigations of material-specific properties such as rates of absorption from the lungs may be taken into account.

For action level doses of 1, 20 and 200 mSv, the relationship between the radionuclide activity in the body and excreta and the time after acute intake are expressed graphically. For each monitoring procedure (e.g lung, thyroid or whole body monitoring, urine and faecal assay), the graphs show the range of values, in Bq or Bq d^{-1} as appropriate, which correspond to the specified doses. The graphs were derived using the current suite of biokinetic models (respiratory tract, gastrointestinal tract, and element-specific systemic models) published by the International Commission on Radiological Protection (ICRP).

Account is taken of the potential variability in:

- Aerosol size (0.1 to 100 µm activity median aerodynamic diameter);
- Solubility and absorption from lungs of the inhaled radionuclides (default types F, M and S as proposed by ICRP);
- Breathing rates of exposed persons;
- Particle clearance rates of exposed persons; and

- For caesium, whole body retention times of exposed persons.

The graphs can be used to deduce whether:

- Doses are acceptably low;
- Treatment should be considered or is unnecessary;
- The monitoring procedure considered is optimal;
- The minimum detectable amount (MDA) of the radionuclide by the preferred monitoring procedure is sufficiently low to assess the specified dose;
- The uncertainty in the assessed dose using a particular monitoring procedure is acceptable; and
- Measurement times can be reduced compared with those used routinely.

Currently this approach is confined to acute intakes of single radionuclides. It is recognised that the more challenging problems in dose assessment will arise from the acute and/or chronic inhalation of mixtures of radionuclides. The information provided here is an essential first stage for addressing these issues since the interpretation of monitoring data will almost certainly be based on the measurements of at least one of the radionuclides considered.

Proposed Action Levels

For adults, it has been suggested by medical officers within Europe and the United States that when the assessed committed effective dose is [Figure A7.1]:

- Below 1 mSv (dark green area), the doses pose a minimum risk to health;
- Between 1 and 20 mSv (light green area), more accurate dose assessment is required. Treatment should not be considered;
- Between 20 and 200 mSv (yellow area), more accurate dose assessment is required. Treatment is subject to medical judgement. Although clinical effects are unlikely to occur, the potential efficacy of initial short-term treatment should be considered; and
- Above 200 mSv (red area), treatment should be considered. However, psychological factors and the potential efficacy of extended or protracted treatment should be considered.

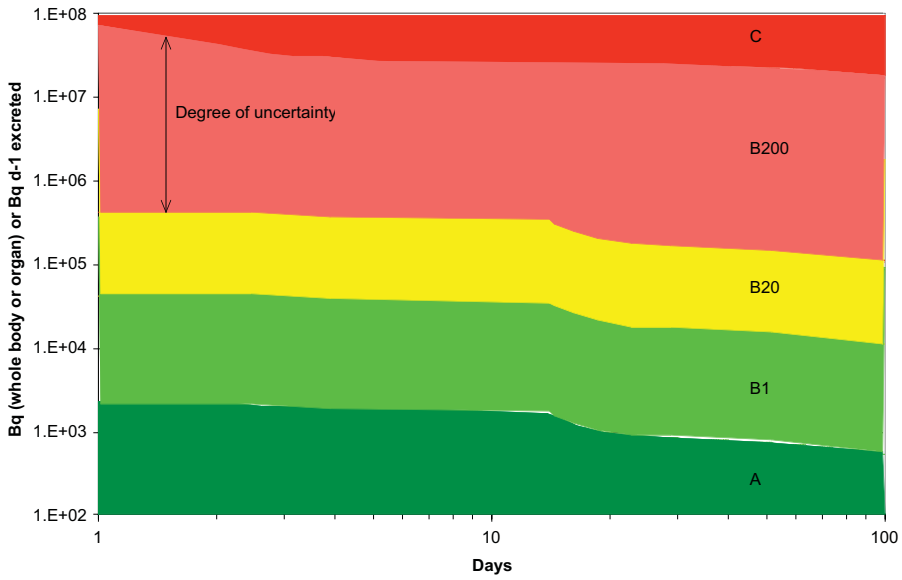


Figure A7.1. The TIARA method (Menetrier et al, 2007b). Figure also presented in Information H.41.

Notes
1. The y-axis shows the measured amount of the radionuclide in whole body or organ of the body, expressed in Bq, or the measured amount of the radionuclide excreted in urine or faeces per day, expressed in Bq d^{-1}.
2. The x-axis shows the elapsed time of the measurement or sample after intake.
3. This example is for whole-body measurements of ^{137}Cs.

The reference points mean:

A: The committed effective dose is definitely below 1 mSv.
B1: The committed effective dose could be above 1 mSv, BUT is definitely below 20 mSv.
B20: The committed effective dose could be above 20 mSv, BUT is definitely below 200 mSv.
B200: The committed effective dose could be above 200 mSv.
C: The committed effective dose is definitely above 200 mSv.

The width of the B200 band represents the range of calculated values of the measured quantity for all combinations of parameters, which in turn indicates the potential uncertainty in dose assessment. The same degree of uncertainty applies to the B1 and B20 bands, but may not be shown because the bands overlap.

Annex 8: Monitoring techniques

Introduction

External radiation

The goal of a field monitoring mission is to understand the radiological hazard and to map the outer border of the contaminated area. There are three major technical challenges:

- Detection;
- Identification; and
- Location of the source.

All these issues have their own characteristics which have to be fully understood and related measures implemented.

Sensitive instruments are required for radionuclide *detection*. Field instruments should be robust and give fast answers. While moving, the monitoring team must use instruments which have a fast response, typically 1 - 5 s. These measurements are interpreted immediately, and the analysis must take into account the variability of the natural background which in many places varies by a factor of ten or more.

Radionuclide identification requires spectrometers. Devices should ideally be easy to operate and be designed for first responders, not for nuclear scientists. Automated software is needed to handle the analysis and related statistics correctly.

Location of a point source (RED), particularly if it is moving, may be a very difficult task in large public areas or public events where 100,000 people, or more, are present. The operation requires team work which is carefully planned in advance. In case of large contamination, the location task faces another problem - the instrument readings and the coordinates have to be merged and an overall map needs to be generated.

A range of instruments are available for emergency response. Dose rate measurement, contamination monitoring and concentration measurements of airborne radionuclides are of primary importance. Response to

dispersion of radioactive material may also require fallout measurements.

Routine equipment used for emergency response includes:

- Geiger-Müller detectors (exposure rate, beta dose rate, contamination);
- Ionisation chambers (exposure rate, beta dose rate);
- Proportional counters (contamination, neutron dose);
- Scintillation detectors (exposure rate, alpha and beta contamination, ground deposition, concentration in air, nuclide identification); and
- Solid state detectors (exposure rate, ground deposition, concentration in air, nuclide identification).

If the contaminated area is small, the measurements can be performed on foot with portable radiation detectors. If larger areas have been contaminated, specific field missions with mobile equipment may be needed. Such equipment could be detectors in cars, helicopters or airplanes.

Internal contamination

Direct measurements, *in vivo*, could be necessary to assess the internal exposure of members of the public, from malevolent use of radioactive material. Direct measurements can be used for determination of the body content and distribution of radionuclides that emit penetrating radiation [Table H1]. Three types of *in vivo* measurements that could be necessary:

- Whole-body counting;
- Organ or partial body counting
  - thyroid
  - lung
  - liver
  - bone; and
- Wound counting.

Detectors that could be used in *in vivo* monitoring:

- Scintillation detectors;
- Semiconductor detectors;
- Gas filled detectors;
- Liquid scintillation detectors; and
- Gamma cameras.

External radiation

In most scenarios the following initial monitoring tasks are usually carried out:

- Mapping of the Red Zone boundary;
- Monitoring of the Red Zone expansion;
- Screening for hot spots outside the Red Zone;
- Monitoring of people coming out of the Red Zone; and
- Identification of the radionuclides present.

In case of contamination of food and water supplies, environmental monitoring techniques are usually needed, but in all other scenarios the above mentioned tasks are usually applicable. In case of beta or alpha emitting radionulides, the first four tasks require alpha/beta contamination monitors to be used. This makes the tasks quite straight forward to execute, but makes them time consuming and tedious.

In case of gamma emitting radionuclides the choice of measurement instruments is much broader, but some instruments are more suitable for certain tasks than others. The correct deployment of the available instruments can speed up the tasks considerably. The following paragraphs describe the deployment of various detectors in an incident involving gamma radiation.

Mapping of the Red Zone boundary is a relatively easy task to undertake. The boundary is marked at the 100 µSv/h dose rate level. Dose rates this high are easily detected even with the most insensitive Geiger-Müller (GM) tube based dose rate meter. With this in mind the more sensitive GM-tube instruments and even more sensitive solid state detectors should not be wasted on the Red Zone mapping task, if possible.

Monitoring of the Red Zone expansion is also a task for the less sensitive instruments. The goal is to detect the rise of the dose rate above 100 µSv/h, which is an easy task for all dose rate meters. Monitoring can be done either by a measurement team(s) patrolling around the Red Zone or by using dose rate meters with loud audible alarms, so that the meter can be positioned e.g. on a tripod some distance outside the Red Zone and no personnel are needed to constantly monitor the reading. The latter

technique is more advantageous in areas where measurement teams are working nearby with other tasks. These include, for example, public processing area where measurement teams are conducting people monitoring and contamination may spread as a result of the movement of people from more contaminated areas inside the Red Zone.

Effective screening of the hotspots outside the Red Zone requires more sensitive detectors. With more sensitive detectors, sparser search grid can be used and the measurement team can move faster through the grid. Measurement teams should be able to detect hotspots of 100 µSv/h or more at one meter distance. Such a hotspot will produce only 1 µSv/h at 10 meters distance and could be missed if the most insensitive dose rate meters are used and the team passes the source too fast (brisk walking speed). More sensitive GM-tube based dose rate meters or Personal Radiation Detectors (PRDs) with solid state detectors should be able to detect such hotspots from even greater distances. Detection levels are highly dependent of the ambient dose rate. Near the Red Zone, the ambient dose rate from the Red Zone could still be several tens of microsieverts and thus the search for hotspots must be done with much denser search grid than used further away from the Red Zone.

Monitoring of people on the Red Zone border in a gamma radiation incident is also a quite straight forward task for more sensitive dose rate meters or PRDs. Although the ambient radiation from the Red Zone is several tens of microsieverts, a person with significant areas of contamination above the action limit should produce a clearly detectable rise in dose rate. With sensitive PRDs, the monitoring can be done relatively fast (at a pace of one person a minute).

Identification of the radionuclides present is a fairly straight forward task in the case of a point source RED. In dispersion scenarios the case is more complicated. Portable high resolution gamma spectrometers are usually not available in large numbers, so they should not be used inside the Red Zone due to the risk of instrument contamination and the fact that most spectrometers saturate at dose rates below 100 µSv/h. This means that sampling and sample measurements are needed to assess the radionuclides present inside the Red Zone. In the case of an RDD the different nuclides used in the device may have dispersed very differently from each other, which makes representative sampling difficult or practically impossible.

This means that a large number of samples must be taken and measured. However, only short measurement times are usually needed due to the relatively high activities of the samples.

Dose rate measurements

Dose or dose rate measurements from gamma, beta or neutron sources are of primary importance in an emergency. The instruments should have a wide dynamic range from low doses to high doses. Protective clothes and a wide arsenal of in-field equipment can make it difficult to read the display of a monitor in a varying environment, including daylight vs. darkness. Personal dosemeters equipped with alarm functions are necessary for safe operation in the field.

The earliest detection methods for ionising radiation were based on the measurement of ionisation caused by photons in gas. In the ionisation chamber, ions and electrons are attracted to the cathode and anode, respectively, using an electric field. When the strength of the field is high, the gas-filled detectors are known as proportional counters or Geiger-Müller (GM) counters. Information of the energy distribution of the photons can be obtained in the proportional mode. In the Geiger-Müller mode no information on the energy distribution can be obtained. Proportional or Geiger-Müller detectors can also be used for charged particle detection using specially-designed probes with a thin entrance window.

Gas-filled detectors, especially Geiger-Müller counters, are very widely used in civil defence. They have a simple structure. Portable and battery-driven detectors are robust and reliable. The disadvantage is the poor sensitivity which is due to the low gas density. Gas-filled detectors are therefore sub-optimal to locate orphan sources in the environment. However, because of their poor sensitivity, they can be used in intensive radiation fields. Low sensitivity can be partially avoided using gases with high density. Pressurised ionisation chambers are widely used in environmental monitoring. They are suitable for applications where accuracy is required, but their operation may be clumsy, and therefore, they are not often used for emergency response purposes.

Figure A8.1. Examples of gamma dose rate monitors. Photos: HPA (left), STUK (right) .

Figure A8.2. Examples of personal alarming dosemeters. Photos: HPA, STUK.

Caesium iodide (CsI) scintillator together with a small photodiode is nowadays frequently used in hand held personal radiation detectors (PRDs). Because of high density and high atomic number the sensitivity, as compared with the gas-filled detectors, is superior. The monitor is often calibrated using total count rate given by a ^{137}Cs source (662 keV + Compton continuum). This simple approach may lead to an error of 50 % if, for example, the dose rate generated by a high-energy emitter such as ^{60}Co is under investigation. More accurate results are obtainable if the entire energy spectrum could be used for the dose rate estimation.

Some PRDs are actually spectrometers and the dose rate can be calculated from the spectrum. The conversion, or calibration, is made by measuring several different spectra and simultaneously recording the ambient dose equivalent using a well calibrated ionisation chamber as a reference. In field conditions, software automatically converts the spectrum, acquired in short

intervals, to dose rate which then is displayed on the screen in addition to the total count rate. Accuracy of 10 - 20 % is achieved over a wide range of photon energies.

A neutron detector is often integrated into PRD. The modern PRD is easy to use, and it provides the essential information on the prevailing radiation field in a reliable and timely manner.

Figure A8.3. Examples of Personal Radiation Detectors (PRDs). All except one (second from right) are also spectrometers. All except one (right) include neutron monitoring option. Photo: STUK.

The passive, non-alarming thermoluminescent dosemeters (TLD) are widely used for estimation of external doses. The TLD consists of a crystal which gives off light when heated, the light being proportional to the degree of exposure of the TLD. The crystal is usually placed in a holder which contains filters which can be used to differentiate between skin doses and penetrating doses of ionising radiation. The TLD is normally worn on the trunk of the body, but can also be worn on the extremities (e.g. for measuring dose to the fingers). Among the advantages of this method are its high sensitivity, long-term storage of information (accumulated dose) and the possibility of full automation of measurements and data processing.

Figure A8.4. Examples of ThermoLuminescent Dosemeters (TLDs). Photo: HPA.

Detection of beta and alpha emitters

External beta radiation may damage the skin and the tissue underneath. This is due to the short range of beta particles (less than about 1 cm in tissue). Thus, localised radiation burns are possible, particularly if beta emitting sources are in contact with skin. Highly active particles, often referred to as hot particles, may even generate point-like radiation burns to the skin.

Skin dose rate can be evaluated in different ways depending on the location of the contamination. If the surface activity of the skin is known (Bq/cm^2), precalculated dose rate conversion factors can be used for the dose estimation. Computer codes, such as VARSKIN, may also be useful (Durham, 1992). Since neither the nuclide nor its activity is generally known, the dose can be roughly estimated by measuring the total number of beta emissions during the skin exposure.

Surface contamination can be measured using a beta contamination monitor; a suitable device is a Geiger-Müller counter equipped with a beta probe which has a thin (aluminium) window. The probe should be calibrated against the known surface contamination to obtain the correct number of beta emissions. Beta dose rate monitors can be calibrated to show equivalent skin doses.

Figure A8.5. An example of a beta dose rate monitor. Photo: HPA.

Gas-filled detectors are suitable for the detection of alpha emitters, if the window material is made of light elements, typically beryllium (25 - 50 µm). With this device, soft gamma rays and X-rays (< 30 keV) may also be detected.

Figure A8.6. Examples of alpha contamination monitors. Photos: HPA.

Figure A8.7. An example of beta and X-ray contamination monitor. Photo: HPA.

Figure A8.8. An example of alpha, beta and gamma contamination monitor. Photo: STUK.

Neutron counting

Nuclear materials typically emit alpha particles, photons, X-rays and neutrons. The neutron radiation is a very characteristic feature of nuclear materials, such as plutonium, and it is difficult to shield. Neutron detection is therefore an efficient way to monitor the presence of nuclear materials. However, neutron detection is more difficult than gamma detection.

Neutrons are detected as a result of the nuclear reaction of a neutron with a nucleus resulting in detectable charged particles. The most common neutron detector is a pressurised ^{3}He filled tube. Other widely used compounds are $^{10}BF_3$, ^{6}Li and ^{10}B. $^{10}BF_3$ is gaseous and is used in proportional counters. Solid state detectors are either scintillation material or semiconductors that are doped with boron or lithium. The disintegration of lithium or boron produces charged particles that further produce scintillations.

The scintillation materials may be sensitive to gamma radiation, which has to be discriminated from the neutron pulses. The separation of neutron and gamma events in a gamma sensitive neutron detector is performed either by pulse height discrimination or pulse shape discrimination. Table A8.1 contains a summary of neutron detection materials and their main characteristics.

Table A8.1. Neutron detection materials and their properties. Efficiency is defined as percentage of detected neutrons/neutron fluence. Detectors based on gamma sensitive materials require a mean to discriminate between gamma and neutron pulses.

Material	Efficiency	Gamma sensitivity	Type
BF_3 gas	<10 %	yes	high pressure tube
^3He gas	~30 %	yes	high pressure tube
LiI	25-30 % (~100 % for enriched ^6Li)	yes	scintillator
Li in ZnS(Ag)	60 %	low	scintillator
Li doped glass	80 %	low	scintillator
B_4C	50-80 % (thin layer)	low	semiconductor
Si Pin diode Cd foil	<10 %	yes	semiconductor

Portable detectors are mainly based on proportional counters. The advantage of the gas-filled tube is the simplicity of the readout electronics and the discrimination is fairly easy to implement.

Figure A8.9. Example of a hand held monitor for measuring neutron dose rate. Photo: HPA.

Nuclide identification using gamma spectroscopy

Most radioactive substances produce gamma rays of various energies and intensities. A detailed analysis of a collected gamma spectrum is typically used to determine the identity and quantity of gamma emitters present in the source. The equipment used in gamma spectroscopy includes an energy sensitive radiation detector, amplifiers, multichannel analyser and data readout devices. Gamma spectroscopy systems are selected to take advantage of several performance characteristics. Two important characteristics are resolution and efficiency. The most common detectors include sodium iodide (NaI) scintillation counters and semiconductor detectors, e.g. high purity germanium detectors (HPGe).

Scintillation detectors use crystals that emit light when gamma rays interact with the atoms in the crystals. The intensity of the light produced is proportional to the energy deposited in the crystal by the gamma ray. The detectors are joined to photomultipliers that convert the light into electrons and then amplify the electrical signal provided by those electrons. Common scintillators include thallium-doped sodium iodide, NaI(Tl), or caesium iodide, CsI(Tl), detectors. Because of the poor resolution of NaI and CsI based detectors, they are not suitable for the identification of complicated mixtures of gamma ray producing materials. Scenarios requiring such analyses require detectors with higher resolution, like HPGe.

Semiconductor detectors, also called solid state detectors, are fundamentally different from scintillation detectors. They use a semiconductor to detect traversing charged particles or the absorption of photons. In these detectors, radiation is measured by means of the number of charge carriers set free in the detector, which is arranged between two electrodes. Common semiconductor based detectors include germanium, cadmium zinc telluride (CZT) and lanthanium bromide ($LaBr_3$). High purity germanium (HPGe) detectors produce the highest resolution commonly available today, which makes them optimal for nuclide identification. A draw back of these detectors is that cryogenic temperatures are vital to the operation.

Figure A8.10. Examples of NaI(Tl) detector based monitors used as gamma contamination monitors. Photos: HPA.

Figure A8.11. Example of portable gamma spectrometry equipment. Photo: STUK.

Figure A8.12. Examples of Radionuclide Identification Devices. All are gamma spectrometers with a neutron monitoring option. Photos: STUK.

Figure A8.13. An example of a radiation surveillance vehicle and mobile laboratory. The laboratory is equipped for dose rate monitoring, nuclide identification, aerosol sampling, sample and in situ gamma spectroscopy measurements and alpha spectroscopy measurements, as well as operational voice and data communication. Photo: STUK.

Wipe tests

Wipe tests are used both for determination of environmental surface contamination [Instructions E.18 and Information E.18:2e] and for skin contamination. The wipe test measures only the contamination that can be removed from the surface. For determination of surface contamination a filter paper may be used to wipe the surface. Wipe approximately an area 10 cm x 10 cm with the dry or moistenned filter paper. A background sample is also needed. Frequently, the amount of activity removed fram a surface by a wipe, is assumed to be 10 %. This is known as the removal factor. If the measurement result of a sample is three to four times higher than the background, it can be concluded that contamination is present.

The contamination monitoring equipment used depends on the type and energy of the ionising radiation. In general, for beta emitters a GM counter can be used, while for gamma emitters a scintillation counter or a gamma spectrometer can be used.

The ISO 7503-1 standard gives a description of the calibration procedure and sampling for surface contamination measurements. The surface contamination is measured in Bq/cm². It is proportional to the net counting rate and a calibration factor. The calibration factor is a function of the instrument's efficiency for the specified radionuclide, the area wiped, the source efficiency and the removal factor.

Internal contamination

Whole body measurement with specially designed whole body counters

Whole body counting with special equipment can only be done in dedicated laboratories (fixed or transportable). Such measurements are time consuming and not always suitable for rapid measurements of large groups of people. No instructions for this type of measurements will be given in the Handbook. For such measurements, contact experts that will give their advice on where the whole body counting measurements and the dose assessments can be made.

Several commercial systems exist for the rapid monitoring of the whole body in a routine, radiological protection context. These may consist of a

booth in which the subject stands upright in front of, or possibly between, arrays of stationary detectors. In other designs, a single detector (HPGe or large NaI(Tl)) may perform a scan of the body, with the possibility of delivering crude indications of how any internal contamination is distributed. If installed software is employed to produce estimates of body content based on a built-in library of calibration spectra, the validity of the calibration needs to be assessed in relation to the particular conditions of measurement.

Some organisations have monitors installed in vehicles for regular monitoring of workers. These monitors could conveniently be brought into service.

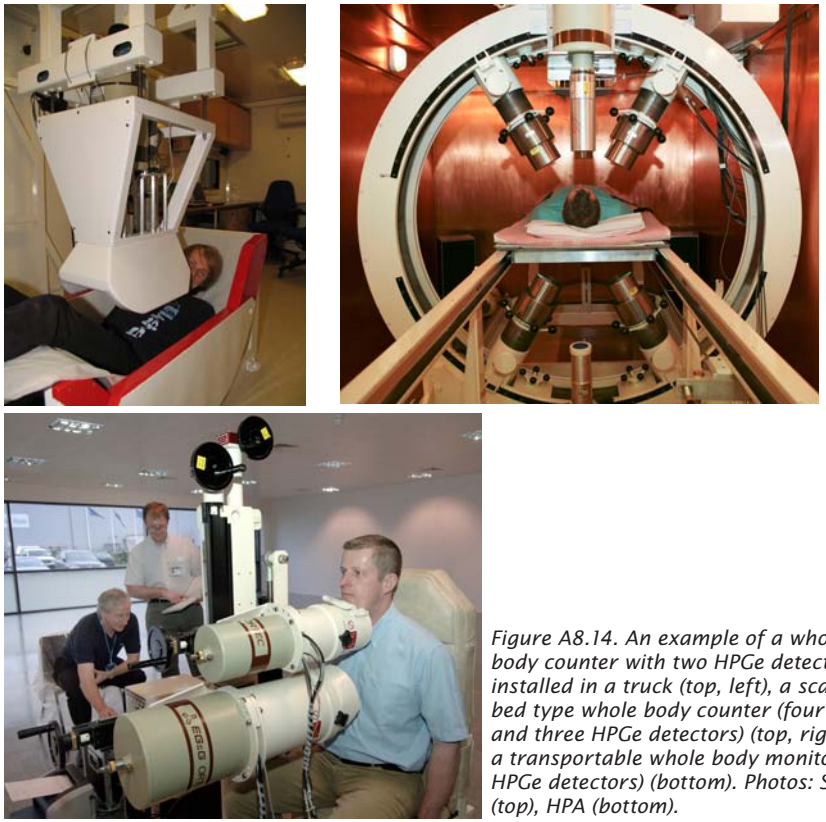


Figure A8.14. An example of a whole body counter with two HPGe detectors installed in a truck (top, left), a scanning bed type whole body counter (four NaI(Tl) and three HPGe detectors) (top, right) and a transportable whole body monitor (two HPGe detectors) (bottom). Photos: STUK (top), HPA (bottom).

Improvised *in vivo* monitoring arrangements

As an alternative to importing dedicated or established facilities, arrangements may be improvised, making use of any suitable scintillation counter (including possibly a gamma camera with collimator removed) or large semi-conductor (germanium etc.) detector. These arrangements can be made sufficiently flexible to allow:

- For adjustment of detector and subject position in optimising count rate and accuracy; and
- For collimators to be fitted where activity must be assessed in specific organs.

Various geometries exist for assessment of whole body contamination. They include:

- Arc geometry: the subject reclines on a curved bed so that all parts of the body are roughly equidistant from a detector located at 1-2 metres distance;
- Simple arrangements, in which the subject stands or lies with the abdomen located on the axis of the detector at a 1 metre (or greater) distance; and
- Chair geometry: the subject is seated with the detector located at (typically) 0.4 m distance from the trunk and thighs.

The approach adopted will be influenced by several factors including the detectors available, the anticipated distribution of radionuclides in the body, the possible need to accommodate sick or injured people, and the availability of appropriate shielding. At the lower end of the activity range under consideration (10^4-10^7 Bq), partial shielding would be required to achieve adequate statistical reliability in a short counting time. Local shielding of the detector, to the extent possible without impairing its sensitivity to activity in the subject, may be considered. Shielding of the subject, on all sides except the one exposed to the detector, is recommended. In the absence of such shielding, the subject's presence may modify the ambient radiation field, and it may be important to reproduce the relevant conditions when recording the background response. Precautions will include the provision of an appropriate inactive phantom in place of the subject. As a guide to the thickness of such shielding, the aim should be for 50 mm of lead or its equivalent in some other material

such as steel. In practice, weight limitations may dictate less effective shielding. The frequency of background checks should be chosen taking into account the importance of early detection of surface contamination brought into the shielded region, or of variations in the local background arising from meteorological changes.

If it is necessary to assess the activity of radionuclides in specific organs or regions of the body, the detector used for whole body monitoring may be fitted with a suitable collimator. In the specific case of monitoring the thyroid for radioiodine, it is best to use a small detector, preferably collimated. Suitable materials should be used to shield parts of the body that may have irremovable surface contamination, to avoid erroneous assessments of internal contamination. If the affected areas are so extensive that this approach is inapplicable, excretion analysis will be required to provide a basis for the assessment of committed effective dose.

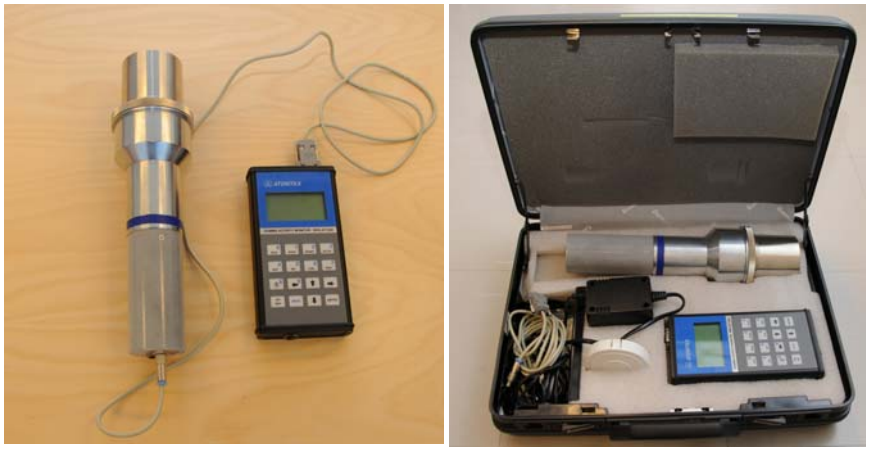


Figure A8.15. Examples of simple NaI(Tl) gamma spectrometric equipment for whole body and thyroid measurements. Photos: STUK.

The accuracy of measurements

The continued validity of an adopted calibration should be confirmed daily, through measurements of a designated reference point source in a fixed and reproducible geometry. As further confirmation, there should, in addition, be occasional re-measurements of the response to a phantom containing a known quanitity of a single radionuclide. Results with an estimated accuracy of a factor of 2 or better, are often adequate. There may later be a

case for more rigorous assessment of internal contamination and ensuing exposure in a representative subgroup of those monitored with simple systems.

Some examples of instruments and calibration factors for whole body measurements of ^{137}Cs and measurements of ^{131}I in the thyroid are given in Tables A8.2-A8.5. The calibration factors for the instruments available need to be determined in advance by the local monitoring specialists.

Measurement of ^{137}Cs with gamma cameras

Gamma cameras at hospitals can be used for contamination monitoring when large groups of people need to be measured in emergency situations or when no other whole body counting equipment is available. An advantage is the trained personnel with experience from such measurements. If the camera is used without collimator and placed close to the body of the person to be measured, care should be taken to arrange for mechanical stability of the configuration. The background variations in certain emergency situations and the shielding effect of other persons close to the camera cause the highest uncertainties.

Table A8.2. Calibration of hand held instruments for measurements of ^{137}Cs in humans for two different measurement geometries. The activity is calculated by dividing the background substracted measurement value by the calibration factor. Detector in contact with the body (Rahola et al, 2006).

Manufacture	Type	Type of detector	Detector size	Measurement geometry	Calibration factor[1]
BICRON	ANALYST	NaI(Tl)	50 × 50 mm	Back	$2.5x10^{-3}$
BICRON	ANALYST	NaI(Tl)	50 × 50 mm	Palmer (lap)	$3.9x10^{-3}$
SAPHYMO-STEL	SPP2	NaI(Tl)	25 × 50 mm	Palmer (lap)	$7.9x10^{-4}$
RADOS	SRV-2000	GM detector		Palmer (lap)	$6x10^{-7}$
Exploranium	Gr-110s	NaI(Tl)	38 × 38 × 50 mm	Palmer (lap)	$1x10^{-3}$
Exploranium	Gr-110s	NaI(Tl)	38 × 38 × 50 mm	Back	$1.1x10^{-3}$
RNI	10	GM detector		Palmer (lap)	$1.3x10^{-6}$
RNI	10	GM detector		Back	$6.3x10^{-7}$
Morgan	Minimonitor 900	NaI(Tl)	25 × 19 mm	Back	$9.5x10^{-5}$
Morgan	Minimonitor 900	NaI(Tl)	2,5 × 32 mm	Back	$3.8x10^{-4}$
Morgan	Minimonitor 900	NaI(Tl)	25 × 19 mm	Palmer (lap)	$9.5x10^{-5}$
Morgan	Minimonitor 900	NaI(Tl)	2,5 × 32 mm	Palmer (lap)	$3.8x10^{-4}$
Made in Russia	SRP-88	NaI(Tl)	25 × 40 mm	Back	$5.7x10^{-5}$
Made in Russia	SRP-88	NaI(Tl)	25 × 40 mm	Palmer (lap)	$1x10^{-4}$

Notes:
1 The calibration factor is given as microsievert/Bq for the scintilation detectors and in cps/Bq for the Geiger-Muller detectors.

Table A8.3. Calibration of hand held instruments for measuring ^{131}I in the thyroid. The instrument placed close to neck (Rahola et al, 2006).

Manufacture	Type	Detectortype	Detector size	Calibration factor[1]
BICRON	ANALYST	NaI(Tl)	50 × 50 mm	0.041
SAPHYMO-STEL	SPP2	NaI(Tl)	25 × 50 mm	0.012
Exploranium	Gr-110s	NaI(Tl)	38 × 38 × 50 mm	0.021
Mini Instruments	6-90 Scaler ratemeter	NaI(Tl)	25 mm	0.0045
RNI	10	GM		0.000016
SAPHYMO-Phy	ADB/AD-6	Plastscint.	76 × 76 mm	0.013
SAPHYMO-Phy	ADB/AD-3R	GM		0.000013
Automess	AD-b/AD-6	Plastscint.	76 × 76 mm	0.013
Automess	6150 AD3 R	GM	18 × 8 mm	0.000013
Made in Russia	SRP-88	NaI(Tl)	25 × 40 mm	0.0012
Morgan	Minimonitor 900	NaI(Tl)	25 × 19 mm	0.0042
Morgan	Minimonitor 900	NaI(Tl)	25 × 32 mm	0.0093

Notes:
1. The calibration factor is given as microsievert/Bq for the scintilation detectors and in cps/Bq for the Geiger-Muller detectors.

Table A8.4. MDA and sensitivity for measurement of ^{137}Cs and ^{131}I with gamma camera in different configurations (choice of collimator and detector height). Before the activity calculation, the background has been subtracted (Wallström et al, 1999).

Energy interval (keV)	**Colli-mator**	**Phantom size (kg)**	**MDA ^{137}Cs in whole body (kBq)**		**MDA ^{131}I in thyroid (kBq)**		**Sensitivity ^{137}Cs in whole body, centered (cps/kBq)**		**Sensitivity ^{131}I in thyroid, neck (cps/kBq)**	
			5 cm	35 cm	10 cm	40 cm	5 cm	35 cm	10 cm	40 cm
50-450	None	14	0.25	0.90			78	24		
		61	0.40	1.0	0.10	0.45	46	21	170	47
		93	0.45	1.1			39	18		
	LEGP	14	0.80	2.3			9.1	3.3		
		61	2.1	3.5	0.80	2.5	3.8	2.2	9.8	3.4
		93	2.3	4.2			3.0	1.7		
	HEGP	14	3.6	8.5						
		61	12		13	17				
		93	11	17						
550-750	None	14	0.30	1.3			12	3.2		
		61	0.70	2.0	1.5	9.0	5.4	2.2	2.6	0.47
		93	1.6	3.2			2.2	1.2		
	LEGP	14	1.1	2.9			2.9	1.1		
		61	2.5	4.9	4.5	20	1.2	0.64	0.67	0.16
		93	3.0	5.8			0.93	0.52		
	HEGP	14	7.0	17						
		61	13	31	26	47				
		93	11	27						

Table A8.5. Technical characteristics of detectors used in assessing internal radioactive contamination in the local population following the reactor accident at Chernobyl. Table adapted from IAEA TECDOC 746,1994.

Unit type	**Mass [kg]**	**Detector size (diameter, thickness, mm)**	**Shielding**	**Measurement geometry**	**Signal processing**	**Throughput measurements/ hour**	**MDA, kBq**	**Application**
NC25, "gamma thyroid radiometer"	120	40, 40	lead colli-mator	150-200 mm from neck	SCA, digital output analogue	100	1	^{131}I in thyroid
SRP-68-01, gamma dosemeter	6	20, 20	none	close to neck close to abdomen	rate meter [wide energy band]	60	6 2	^{131}I in thyroid whole body ^{137}Cs + ^{134}Cs
OMEGA800, medical gamma camera without collimator	600	500, 8	none	450 mm above supine thorax	SCA	35	4	whole body ^{137}Cs + ^{134}Cs
QBM-1A, "quick body monitor"	200	0.3 m^2	partial 8-10 mm Pb	chair	SCA	60	0.5	whole body ^{137}Cs + ^{134}Cs
WBC25, transportable whole body counter	450	75, 75	partial, 20-50 mm Pb	chair	MCA	36	1	whole body ^{137}Cs + ^{134}Cs
WBC22, established whole body counter	3500	203, 102	totally enclosed 150 mm steel	chair	MCA	10	0.04	whole body ^{137}Cs + ^{134}Cs

Annex 9: Biodosimetry

1 Recommendations on acute biodosimetry applications in radiation emergencies: general concepts

Clinical signs and symptoms, along with haematological parameters (i.e. kinetics of blood cell counts) provide the basis for medical management in radiation emergencies. Current biological dosimetry methods are mainly based on cytogenetics and electron paramagnetic resonance (EPR). Other approaches and technologies have been proposed for specific situations, such as neutron activation analysis (for neutron exposure).

Molecular and enzymatic markers in body fluids and tissues can be used as indicators for radiation exposure. These assays are usually not specific for radiation, and neither very sensitive nor persistent after radiation exposure. However, many of them can be performed by standard clinical laboratories (C reactive protein, fibrinogen, serum enzymes such as amylase) or laboratories performing DNA damage and mutation expression techniques. Among these assays H2XA nuclear foci detection is very promising, but the assay can only be used if the time interval between exposure and detection is very short (i.e. hours). Consequently, this method is not practical at the moment for emergency biological dosimetry.

Reconstruction of doses based on biological dosimetry, is most suitable for exposures to penetrating external irradiation of the whole body or large parts of the body. For non-penetrating radiations (e.g. beta irradiation) and for most cases of exposures from internal contamination (with the exception of gamma emitting radionuclides uniformly distributed in the body, like ^{137}Cs), biological dosimetry does not work well. In the case of the exposure resulting from internal contamination, bioassay measurements can be used to assess internal doses with much greater sensitivity than that obtained with cytogenetic dosimetry. In the case of direct measurements (i.e. on whole body or organs), results can be obtained almost immediately, while indirect measurements (i.e. on excreta) could provide initial results within 48-72 hours, depending on the radionuclide.

No single assay is sufficiently robust to address all potential scenarios, including mass-casualty events. A multi-parameter biodosimetric approach would probably be the best strategy, although it should be adapted according to the magnitude of the event.

2 Biological dosimetry by cytogenetics

[Additional information to Table H2]

Dicentric assay:
Metaphase spread dicentric assay is the gold standard for biological dosimetry. It relates the occurrence of the chromosome aberration called dicentric which is characteristic for ionising radiation and otherwise extremely rare, to the absorbed dose. The method is standardised (ISO 19238, 2004). The dicentric assay requires special expertise and calibration curves (IAEA Technical reports series 260, 1986; IAEA Technical Report series 405, 2001).

Countries with developed nuclear power industry in Europe usually have biological dosimetry laboratories, but there are several European countries without such facilities. It is vital for every country to establish contact with a biological dosimetry laboratory. In Europe there are several leading laboratories (like HPA in UK, IRSN in France, STUK in Finland, and BfS in Germany) and several smaller ones. It takes at least 3-4 days to get the result, counting from the time the blood sample enters the laboratory. The dicentric assay can be used for different types of radiation providing that the calibration curves exist. However, the method has limited usefulness in case of internal contamination, and especially in cases where contaminating nuclides are incorporated in specific organs. Most commonly the method is used for exposure to sparsely ionising radiations like gamma rays or X-rays. Partial body exposure can be estimated using statistical approaches. The dicentric assay can be used in the dose range from 0.1 to 5 Gy. The time between exposure and analysis is not critical, and could extend up to months after exposure. However, for covert exposures that remain undetected for several months, other techniques should be used. There is a limited capacity to perform the assay in each laboratory. Usually, it will not be possible to analyse more than a couple of tens of samples during one week. Consideration for this limitation has triggered development of a “triage” dicentric assay (Lloyd et al, 2000;

Blakely et al, 2005). Such a "triage" approach (ISO 21243, 2008) will make it possible to analyse hundreds of samples per week in some laboratories. "Triage" dicentric assay applies to more than 10 samples in one scenario and categorises the dose range rather than exactly estimating it. Dose categorisation is sufficient for supporting early medical decisions based on medical triage. The minimum detection level for the "triage" approach is around 1 Gy.

Micronucleus assay:
Unlike the dicentric assay micronuclei occurrence is not specific for radiation. The method requires one additional day of culturing as compared to the dicentric assay, but the evaluation step is much faster and does not require the same extensive expertise as dicentric assay. The assay is commonly used for toxicity of different compounds. More laboratories are capable of performing the assay, although very few will have the required calibration information for ionising radiation. The disadvantage of this assay is the variability of the background level due to age and lifestyle factors (Fenech et al, 1999). As for dicentric assay, it will take at least 4 days to perform the assay. The assay can be used in the range from 0.3 to 5 Gy. There are approaches under development for the "triage" micronucleus assay for mass casualty situations (Lloyd et al, 2000). Micronucleus assay is the only technique, among cytogenetic approaches, with a potential for high automation.

Premature chromosome condensation technique (PCC):
Both the dicentric assay and the micronucleus assay have an upper limit for detection of dose of about 5 Gy. This disadvantage can be overcome with PCC. The assay can be used for much higher doses, up to 20-30 Gy for sparsely ionising radiations, and up to 10 Gy for neutrons (Lamadrid et al, 2007). PCC is not as common or standardised as the dicentric or micronucleus assay. It will probably be possible to analyse up to several tens of samples in a laboratory with three analysing persons during one week. Triage approaches are possible for dose categorisation. The assay does not have a high sensitivity at low doses, but it is useful as an assay of choice when people are exposed to high doses. In case of smaller numbers of samples, PCC may be performed together with the classic dicentric assay. PCC in such a case allows estimating the dose when the dicentric assay fails.

FISH related methods:
These methods can be used for small numbers of individuals, but they are labour extensive and the most expensive of all of the cytogenetic techniques. These methods are valuable for retrospective evaluation of exposure, but not for emergency dosimetry. The exception can be fluorescent staining for the automated version for micronucleus assay. FISH related methods will not be addressed further in this Handbook.

3 EPR biodosimetry

These methods are based on the capability to measure free radicals that are created in proportion to the absorbed dose to humans exposed to ionising radiation. These free radical species are extremely stable in non-aqueous media, including teeth, bone, fingernails and hair. The best results for this technique are obtained from measurements in exfoliated or extracted teeth. This is a limitation considering mass casualty situations, and therefore attempts have been made to develop EPR dosimetry for *in vivo* measurements (Williams et al, 2007), but so far they are not well established. EPR is available among others in France, Germany and Finland. EPR in nails can be used up to 30 days after an event and is a promising assay. The minimum detection level for ESR is relatively high, about 1 Gy. The EPR dosimetry requires both very expensive and specialised equipment and a high level of expertise. It will have limited usefulness in the first period after an incident with malevolent use of radiation. Like FISH methods, EPR methods are more useful for retrospective dose assessment (IAEA TECDOC 1331, 2002) and can be used in some cases for evaluation in the late phase of an incident.

4 Other methods

Other methods such as mutation expression and methods related to DNA damage such as H2XA nuclear foci detection are possible, but there are concerns about standardisation, lack of the expertise required and costs. Some of these methods have been used in previous accidents (in Chernobyl and Goiania), but they do not seem easily applicable for malevolent incidents.

Annex 10: Action Levels

This Annex presents Action Levels for the radionuclides, inhalation absorption types and primary monitoring methods listed in Table A10.1. Data is presented for acute intakes by both inhalation and ingestion. The use of these Action Levels is described in Section H.4. The Action Levels are presented in Tables A10.2-A10.18.

Calculations were performed using the ICRP Publication 66 Respiratory Tract Model, the current biokinetic models described in ICRP Publications 30, 56, 67 and 69, and the ICRP Publication 30 gastro-intestinal tract model. Respiratory tract deposition calculations were made using the default physical activity levels given in ICRP Publication 71, and the occupational exposure defaults for particle size parameters (including an Activity Median Aerodynamic Diameter of 5 µm). All calculations were performed for adults.

Table A10.1. Radionuclides and monitoring methods for which Action Levels are presented.

Radionuclide		**Intake mode**	**Absorp. Type** [G]	**GI uptake factor, f_1**	**Primary monitoring method**
		Inhalation or ingestion	**F, M, S**		**Whole body (WB) Lung (L) Thyroid (Th) Urine (U)**
Manganese-54	^{54}Mn	Inhalation	F	0.1	WB
Manganese-54	^{54}Mn	Inhalation	M	0.1	L
Manganese-54	^{54}Mn	Ingestion	-	0.1	WB
Cobalt-60	^{60}Co	Inhalation	M	0.1	L
Cobalt-60	^{60}Co	Inhalation	S	0.05	L
Cobalt-60	^{60}Co	Ingestion	-	0.1 [A]	WB
Selenium-75	^{75}Se	Inhalation	F	0.8	WB
Selenium-75	^{75}Se	Inhalation	M	0.8	WB [C]
Selenium-75	^{75}Se	Ingestion	-	0.8 [B]	WB
Strontium-90	^{90}Sr	Inhalation	F	0.3	U
Strontium-90	^{90}Sr	Inhalation	S	0.01 [D]	U
Strontium-90	^{90}Sr	Ingestion	-	0.3 [E]	U
Silver-110m	^{110m}Ag	Inhalation	F [F]	0.05	WB
Silver-110m	^{110m}Ag	Ingestion	-	0.05	WB
Cadmium-109	^{109}Cd	Inhalation	F [F]	0.05	WB
Cadmium-109	^{109}Cd	Ingestion	-	0.05	WB
Iodine-131	^{131}I	Inhalation	F	1	Th
Iodine-131	^{131}I	Ingestion	-	1	Th
Barium-133	^{133}Ba	Inhalation	F	0.1	WB
Barium-133	^{133}Ba	Ingestion	-	0.1	WB
Caesium-137	^{137}Cs	Inhalation	F	1	WB
Caesium-137	^{137}Cs	Ingestion	-	1	WB
Europium-152	^{152}Eu	Inhalation	M	5E-04	WB
Europium-152	^{152}Eu	Ingestion	-	5E-04	WB
Europium-154	^{154}Eu	Inhalation	M	5E-04	WB
Europium-154	^{154}Eu	Ingestion	-	5E-04	WB
Iridium-192	^{192}Ir	Inhalation	F	0.01	WB
Iridium-192	^{192}Ir	Inhalation	M	0.01	L
Iridium-192	^{192}Ir	Inhalation	S	0.01	L

Iridium-192	^{192}Ir	Ingestion	-	0.01	WB
Polonium-210	^{210}Po	Inhalation	M	0.1	U
Polonium-210	^{210}Po	Ingestion	-	0.1	U
Radium-226	^{226}Ra	Inhalation	M	0.2	L
Radium-226	^{226}Ra	Ingestion	-	0.2	WB
Radium-226	^{226}Ra	Inhalation	M	0.2	U
Radium-226	^{226}Ra	Ingestion	-	0.2	U
Plutonium-238	^{238}Pu	Inhalation	S	1E-05	L
Plutonium-238	^{238}Pu	Ingestion	-	1E-05	WB^{H}
Plutonium-238	^{238}Pu	Inhalation	S	1E-05	U
Plutonium-238	^{238}Pu	Ingestion	-	1E-05	U
Americium-241	^{241}Am	Inhalation	M	5E-04	L
Americium-241	^{241}Am	Ingestion	-	5E-04	WB^{H}
Americium-241	^{241}Am	Inhalation	M	5E-04	U
Americium-241	^{241}Am	Ingestion	-	5E-04	U
Californium-252	^{252}Cf	Inhalation	M	5E-04	U
Californium-252	^{252}Cf	Ingestion	-	5E-04	U

Notes:

A. This f_1 value is for "Type M" compounds, which is the worst case in terms of dose per unit intake (but not necessarily in terms of dose per unit measurement). f_1 is 0.05 for ingestion of "Type S" compounds.

B. This f_1 value is for "Type F" compounds, which is the worst case in terms of dose per unit intake (but not necessarily in terms of dose per unit measurement). f_1 is 0.05 for ingestion of "Type M" compounds.

C. WB selected because of the high f_1 value

D. Type S is appropriate for strontium titanate; all other compounds are assigned to Type F

E. This f_1 value is for "Type F" compounds, which is the worst case in terms of dose per unit intake (but not necessarily in terms of dose per unit measurement). f_1 is 0.01 for ingestion of "Type S" compounds.

F. Type F is appropriate for unspecified compounds and the pure metal. Some specified compounds are assigned to Type M or S, for which specific calculations would be needed.

G. The assignment of Absorption Types to different compounds is given in Table H8.

H. WB measurements would not normally be recommended as a monitoring method for these radionuclides. However, WB should have adequate sensitivity for making comparisons with the upper Action Level (although it is likely the measurement technique would need development by the measurement laboratory). Urine measurements have much better sensitivity, but may be subject to high uncertainties (± an order of magnitude is typical) and could require several days or even weeks before results could be obtained. Where exposures could result in doses close to the upper Action Level, both techniques should ideally be employed.

Table A10.2a. Action Levels for Manganese-54, Inhalation, Type F.

Radio-nuclide	**Action Level on:**	**Method**	**AL_U**					**Initial value for AL_U /AL_L**
			12 h	1 d	3 d	7 d	14 d	
Mn-54 *Type F*	External contamination	External scan	2.7E+06	1.3E+06	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.2E+08	9.5E+07	5.5E+07	4.0E+07	3.1E+07	10
	Internal contamination - primary monitoring method	Whole body	1.2E+08	9.5E+07	5.5E+07	4.0E+07	3.1E+07	10

Table A10.2b. Action Levels for Manganese-54, Inhalation, Type M.

Radio-nuclide	**Action Level on:**	**Method**	**AL_U**					**Initial value for AL_U /AL_L**
			12 h	1 d	3 d	7 d	14 d	
Mn-54 *Type M*	External contamination	External scan	2.7E+06	1.3E+06	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.0E+08	7.8E+07	2.9E+07	1.8E+07	1.5E+07	10
	Internal contamination - primary monitoring method	Lung	1.1E+07	1.1E+07	1.0E+07	9.6E+06	8.5E+06	10

Table A10.2c. Action Levels for Manganese-54, Ingestion.

Radio-nuclide	**Action Level on:**	**Method**	**AL_U**					**Initial value for AL_U /AL_L**
			12 h	**1 d**	**3 d**	**7 d**	**14 d**	
Mn-54	External contamination	External scan	2.7E+06	1.3E+06	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	2.6E+08	2.1E+08	5.8E+07	2.2E+07	1.6E+07	10
	Internal contamination - primary monitoring method	Whole body	2.6E+08	2.1E+08	5.8E+07	2.2E+07	1.6E+07	10

Notes

AL_U - Upper Action Level

AL_L - Lower Action Level

- Comparison with Action Level not valid at these times

Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})

Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.3a. Action Levels for Cobalt-60, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Co-60 *Type M*	External contamination	External scan	2.1E+05	1.1E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.6E+07	1.2E+07	4.0E+06	2.2E+06	1.9E+06	*10*
	Internal contamination - primary monitoring method	Lung	1.8E+06	1.7E+06	1.7E+06	1.6E+06	1.4E+06	10

Table A10.3b. Action Levels for Cobalt-60, Inhalation, Type S.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_{LI}
			12 h	1 d	3 d	7 d	14 d	
Co-60 *Type S*	External contamination	External scan	2.1E+05	1.1E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	6.7E+06	5.0E+06	1.6E+06	8.4E+05	7.6E+05	10
	Internal contamination - primary monitoring method	Lung	8.3E+05	8.0E+05	7.7E+05	7.4E+05	6.9E+05	10

Table A10.3c. Action Levels for Cobalt-60, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	**1 d**	**3 d**	**7 d**	**14 d**	
Co-60 *Type M*	External contamination	External scan	2.1E+05	1.1E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	5.4E+07	4.2E+07	9.6E+06	2.2E+06	1.5E+06	10
	Internal contamination - primary monitoring method	Whole body	5.4E+07	4.2E+07	9.6E+06	2.2E+06	1.5E+06	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.4a. Action Levels for Selenium-75, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Se-75 *Type F*	External contamination	External scan	1.2E+06	6.0E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	9.4E+07	8.1E+07	6.0E+07	5.2E+07	4.5E+07	10
	Internal contamination - primary monitoring method	Whole body	9.4E+07	8.1E+07	6.0E+07	5.2E+07	4.5E+07	10

Table A10.4b. Action Levels for Selenium-75, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Se-75 *Type M*	External contamination	External scan	1.2E+06	6.0E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	7.7E+07	6.5E+07	4.7E+07	4.0E+07	3.5E+07	10
	Internal contamination - primary monitoring method	Whole body	7.7E+07	6.5E+07	4.7E+07	4.0E+07	3.5E+07	10

Table A10.4c. Action Levels for Selenium-75, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	**1 d**	**3 d**	**7 d**	**14 d**	
Se-75	External contamination	External scan	1.2E+06	6.0E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	7.5E+07	7.0E+07	5.9E+07	5.1E+07	4.4E+07	10
	Internal contamination - primary monitoring method	Whole body	7.5E+07	7.0E+07	5.9E+07	5.1E+07	4.4E+07	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.5a. Action Levels for Strontium-90, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Sr-90 *Type F*	External contamination	External scan	4.8E+04	2.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	4.5E+05	1.0E+05	4.2E+04	1.9E+04	10

Table A10.5b. Action Levels for Strontium-90, Inhalation, Type S.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Sr-90 *Type S*	External contamination	External scan	4.8E+04	2.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	1.7E+03	4.7E+02	1.9E+02	9.3E+01	10

Table A10.5c. Action Levels for Strontium-90, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	**1 d**	**3 d**	**7 d**	**14 d**	
Sr-90	External contamination	External scan	4.8E+04	2.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	4.1E+05	1.0E+05	4.1E+04	1.8E+04	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
~ No Action Level available
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.6a. Action Levels for Silver-110m, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ag-110m *Type F*	External contamination	External scan	2.5E+05	1.2E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.9E+07	1.6E+07	9.5E+06	7.6E+06	6.6E+06	10
	Internal contamination - primary monitoring method	Whole body	1.9E+07	1.6E+07	9.5E+06	7.6E+06	6.6E+06	10

Table A10. 6b. Action Levels for Silver-110m, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ag-110m	External contamination	External scan	2.5E+05	1.2E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	6.7E+07	5.2E+07	1.2E+07	3.3E+06	2.7E+06	10
	Internal contamination - primary monitoring method	Whole body	6.7E+07	5.2E+07	1.2E+07	3.3E+06	2.7E+06	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.7a. Action Levels for Cadmium-109, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cd-109 *Type F*	External contamination	External scan	3.1E+05	1.5E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.3E+07	1.1E+07	6.8E+06	6.0E+06	5.9E+06	10
	Internal contamination - primary monitoring method	Whole body	1.3E+07	1.1E+07	6.8E+06	6.0E+06	5.9E+06	10

Table A10.7b. Action Levels for Cadmium-109, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cd-109	External contamination	External scan	3.1E+05	1.5E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	9.4E+07	7.3E+07	1.7E+07	5.2E+06	4.9E+06	10
	Internal contamination - primary monitoring method	Whole body	9.4E+07	7.3E+07	1.7E+07	5.2E+06	4.9E+06	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.8a. Action Levels for Iodine-131, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
I-131 *Type F*	External contamination	External scan	1.0E+05	5.2E+04	-	-	-	10
	Internal contamination - rapid initial screening	Thyroid (rapid)	1.7E+06	2.3E+06	2.1E+06	1.4E+06	7.3E+05	10
	Internal contamination - primary monitoring method	Thyroid	1.7E+06	2.3E+06	2.1E+06	1.4E+06	7.3E+05	10

Table A10.8b. Action Levels for Iodine-131, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
I-131	External contamination	External scan	1.0E+05	5.2E+04	-	-	-	10
	Internal contamination - rapid initial screening	Thyroid (rapid)	1.4E+06	2.2E+06	2.1E+06	1.4E+06	7.5E+05	10
	Internal contamination - primary monitoring method	Thyroid	1.4E+06	2.2E+06	2.1E+06	1.4E+06	7.5E+05	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.9a. Action Levels for Barium-133, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ba-133 *Type F*	External contamination	External scan	1.3E+06	6.4E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	6.9E+07	5.3E+07	1.8E+07	6.2E+06	4.0E+06	10
	Internal contamination - primary monitoring method	Whole body	6.9E+07	5.3E+07	1.8E+07	6.2E+06	4.0E+06	10

Table A10.9b. Action Levels for Barium-133, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ba-133	External contamination	External scan	1.3E+06	6.4E+05	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.9E+08	1.4E+08	3.2E+07	4.2E+06	2.4E+06	10
	Internal contamination - primary monitoring method	Whole body	1.9E+08	1.4E+08	3.2E+07	4.2E+06	2.4E+06	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.10a. Action Levels for Caesium-137, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_u					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cs-137 *Type F*	External contamination	External scan	1.0E+05	5.2E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	2.0E+07	1.8E+07	1.4E+07	1.3E+07	1.2E+07	10
	Internal contamination - primary monitoring method	Whole body	2.0E+07	1.8E+07	1.4E+07	1.3E+07	1.2E+07	10

Table A10.10b. Action Levels for Caesium-137, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cs-137	External contamination	External scan	1.0E+05	5.2E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.5E+07	1.5E+07	1.4E+07	1.3E+07	1.2E+07	10
	Internal contamination - primary monitoring method	Whole body	1.5E+07	1.5E+07	1.4E+07	1.3E+07	1.2E+07	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.11a. Action Levels for Europium-152, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Eu-152 *Type M*	External contamination	External scan	1.8E+05	9.1E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	4.2E+06	3.2E+06	1.1E+06	6.0E+05	5.6E+05	10
	Internal contamination - primary monitoring method	Whole body	4.2E+06	3.2E+06	1.1E+06	6.0E+05	5.6E+05	10

Table A10.11b. Action Levels for Europium-152, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Eu-152	External contamination	External scan	1.8E+05	9.1E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.4E+08	1.1E+08	1.9E+07	4.4E+05	6.1E+04	10
	Internal contamination - primary monitoring method	Whole body	1.4E+08	1.1E+08	1.9E+07	4.4E+05	6.1E+04	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.12a. Action Levels for Europium-154, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Eu-154 *Type M*	External contamination	External scan	7.9E+04	4.0E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	3.3E+06	2.5E+06	8.2E+05	4.6E+05	4.3E+05	10
	Internal contamination - primary monitoring method	Whole body	3.3E+06	2.5E+06	8.2E+05	4.6E+05	4.3E+05	10

Table A10.12b. Action Levels for Europium-154, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Eu-154	External contamination	External scan	7.9E+04	4.0E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	9.2E+07	7.1E+07	1.3E+07	2.9E+05	4.1E+04	10
	Internal contamination - primary monitoring method	Whole body	9.2E+07	7.1E+07	1.3E+07	2.9E+05	4.1E+04	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.13a. Action Levels for Iridium-192, Inhalation, Type F.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ir-192 *Type F*	External contamination	External scan	8.8E+04	4.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	5.8E+07	4.6E+07	2.4E+07	1.8E+07	1.5E+07	10
	Internal contamination - primary monitoring method	Whole body	5.8E+07	4.6E+07	2.4E+07	1.8E+07	1.5E+07	10

Table A10.13b. Action Levels for Iridium-192, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ir-192 *Type M*	External contamination	External scan	8.8E+04	4.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	2.9E+07	2.1E+07	7.0E+06	3.7E+06	3.2E+06	10
	Internal contamination - primary monitoring method	Lung	3.2E+06	3.0E+06	2.8E+06	2.6E+06	2.2E+06	10

Table A10.13c. Action Levels for Iridium-192, Inhalation, Type S.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ir-192 *Type S*	External contamination	External scan	8.8E+04	4.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	2.3E+07	1.8E+07	5.3E+06	2.6E+06	2.3E+06	10
	Internal contamination - primary monitoring method	Lung	2.9E+06	2.8E+06	2.6E+06	2.4E+06	2.1E+06	10

Table A10.13d. Action Levels for Iridium-192, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ir-192	External contamination	External scan	8.8E+04	4.4E+04	-	-	-	10
	Internal contamination - rapid initial screening	Whole body (rapid)	1.4E+08	1.0E+08	2.0E+07	1.3E+06	8.6E+05	10
	Internal contamination - primary monitoring method	Whole body	1.4E+08	1.0E+08	2.0E+07	1.3E+06	8.6E+05	10

Notes

AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.14a. Action Levels for Polonium-210, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Po-210 *Type M*	External contamination	External scan	2.4E+11	1.2E+11	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	1.2E+01	2.4E+01	2.3E+01	2.1E+01	10

Table A10.14b. Action Levels for Polonium-210, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Po-210	External contamination	External scan	2.4E+11	1.2E+11	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	1.6E+02	3.6E+02	3.4E+02	2.9E+02	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
~ No Action Level available
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.15a. Action Levels for Radium-226, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ra-226 *Type M*	External contamination	External scan	~	~	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Lung	5.7E+03	5.5E+03	5.2E+03	4.9E+03	4.4E+03	10

Table A10.15b. Action Levels for Radium-226, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Ra-226	External contamination	External scan	~	~	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Whole body	6.8E+05	5.3E+05	1.4E+05	3.0E+04	1.8E+04	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
~ No Action Level available
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.16a. Action Levels for Plutonium-238, Inhalation, Type S.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Pu-238 *Type S*	External contamination	External scan	4.5E+07	2.3E+07	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Lung	1.6E+03	1.5E+03	1.5E+03	1.4E+03	1.3E+03	10
	Internal contamination - primary monitoring method	Urine	-	4.7E-02	1.7E-02	6.7E-03	4.2E-03	10

Table A10.16b. Action Levels for Plutonium-238, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Pu-238	External contamination	External scan	4.5E+07	2.3E+07	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Whole body	2.1E+07	1.6E+07	3.0E+06	5.8E+04	2.7E+02	10
	Internal contamination - primary monitoring method	Urine	-	1.5E+00	6.5E-01	1.6E-01	5.0E-02	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
~ No Action Level available
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.17a. Action Levels for Americium-241, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Am-241 *Type M*	External contamination	External scan	8.8E+06	4.4E+06	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	1.2E+01	9.0E-01	4.1E-01	3.0E-01	
	Internal contamination - primary monitoring method	Lung	4.7E+02	4.5E+02	4.3E+02	4.1E+02	3.7E+02	10

Table A10.17b. Action Levels for Americium-241, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Am-241	External contamination	External scan	~	~	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	2.9E+01	2.2E+00	6.5E-01	3.5E-01	
	Internal contamination - primary monitoring method	Whole body	9.1E+05	7.0E+05	1.3E+05	3.0E+03	4.4E+02	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
~ No Action Level available
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Table A10.18a. Action Levels for Californium-252, Inhalation, Type M.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cf-252 *Type M*	External contamination	External scan	5.2E+07	2.6E+07	-	-	-	10
	Internal contamination - rapid initial screening	Nose blow	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	1.8E+01	3.3E-01	2.2E-01	2.0E-01	10

Table A10.18b. Action Levels for Californium-252, Ingestion.

Radio-nuclide	Action Level on:	Method	AL_U					Initial value for AL_U /AL_L
			12 h	1 d	3 d	7 d	14 d	
Cf-252	External contamination	External scan	~	~	-	-	-	10
	Internal contamination - rapid initial screening	None	~	~	~	~	~	10
	Internal contamination - primary monitoring method	Urine	-	4.6E+01	5.7E-01	2.7E-02	2.6E-02	10

Notes
AL_U - Upper Action Level
AL_L - Lower Action Level
- Comparison with Action Level not valid at these times
~ No Action Level available
Action Levels are expressed in Bq, except for external contamination (Bq cm^{-2}) and urinary excretion (Bq d^{-1})
Dose calculations were performed using the same assumptions as specified in Annex 13

Annex 11: Sampling of excreta and blood

All excreta and blood samples can carry hazardous organisms and the unsterilised samples must be handled with care, preferably following guidelines laid down for the handling of biohazardous materials by the relevant national health and safety authority. Preferably staff handling such samples should be inoculated against hepatitis A and B and polio. Full protection may not be obtained up until a year after the commencement of an inoculation programme [Instructions F.81 - F.84 and H.22].

Urine samples

The method for collection of urine samples depends on the aim for using the result, confirmation of internal contamination or dose assessment. This can be done if contacts to health care centres are established. There are no internationally agreed procedures for the assay of samples obtained for indirect assessment of levels of radionuclides in the body.

For preliminary determination of radionuclide(s) do a gamma spectrometric measurement. After that, do a beta and/or alpha spectrometric determination, for example using liquid scintillation counting. Remember to avoid contamination of the instruments. If high levels of activity are suspected, the sampling should be done under supervision of trained medical staff with experience of handling radioactive samples. Remember to clean the body area that could contaminate the urine sample. Also continuously take care not to spread contamination during sampling and handling the sample container.

1. Spot sample

Clean containers must be used for collection. From the container the sample is transferred to a clean bottle using a funnel if not taken directly into the bottle. Always take care not to contaminate the bottle or the sample. During sampling, use disposable gloves. Record date and time of sampling as well as personal data.

2. Collection of 24 hour urine samples

In the morning, the person studied empties the bladder completely and the urine is thrown away. The exact clock time is recorded. From this time onwards all urine excreted is collected, and the following morning at the

same time as on the day before, the person empties the bladder the last time into the collection container. It is important to collect all the urine, not loosing any of it for one reason or another. If the concentration determined by direct measurement of the sample is below the detection limit a fast way forward is to concentrate the urine by precipitation (IAEA Safety report series 18, 2000) and measuring the rest by gamma spectrometry and the total beta activity by low background beta counter.

Faecal samples

The typical faecal sample is a single voiding. Health care centers or hospitals should be asked for advice concerning collection of samples. Always use clean (new) containers. Remember to record date and time of sampling as well as personal data on the container. Consult the laboratory analysing the sample for further instructions. This method is not practical for larger contamination events.

Nasal swabs

Radioactivity measured from survey swabs can be used to estimate pulmonary contamination. Lung contamination is estimated to be about 5 % of total radioactivity measured in both nasal swabs.

To take the nasal swab:

1. Swab collection should occur before nasal decontamination, sneezing, nasal trauma, etc.
2. Swab each nostril with moistened cotton tipped swab. Use only one swab per nostril.
3. Survey swabs for the amount of radioactivity present. Presence of alpha emitting radioisotopes will be masked by the water on the cotton swab. Swabs must therefore be allowed to dry fully when surveying for alpha emitters. It would be advisable to measure the sample in a laboratory having a standard procedure for this type of sample. The standard counting geometry used should minimise the effects of non-uniform distribution of activity.
4. Presence of activity in only one nostril suggests non-respiratory source of contamination.

Nose blow

It will not be possible to use nasal swabs as a mass screening technique in a

larger contamination event. A programme of nose blow sampling could be initiated for this purpose.

Procedure for taking and transporting blood samples (according to ISO standard 19238:2004 E) for cytogenetic biodosimetry

[Instruction H.23, Information H.21 and H.23]

1. Make sure that a stock of standard lithium heparin tubes is available. If lithium heparin is unavailable then sodium heparin is acceptable.
2. For each subject, at least 10 ml blood should be taken.
3. Make sure you have the questionnaire for the subjects giving blood. This questionnaire should include at least:
   - Personal data;
   - Relevant medical data (previous medical exposure to radiation, smoking status, information of possible infections);
   - Available information on the exposure (e.g. type of radiation and timing of exposure)
   - Tube label information; and
   - Health service facility identification data.
4. Blood sample taking:
   - Fill in questionnaire together with the person;
   - Collect blood samples to the unambiguously labeled tubes (10 ml from each subject should be taken);
   - Gently rock the tubes for 2 minutes; and
   - Maintain the tubes at room temperature before package.
5. Package and transport of blood samples:

   Blood samples should be transported at approximately 20 °C. Blood samples must not be frozen.

   - Pack blood samples in Styrofoam container (if possible containing room temperature gel-pack; if extreme temperature are likely to occur, it may be an option to include in the package maximum-minimum thermometer);
   - Mark the package with the labels: “Urgent diagnostic samples”, “Not to be frozen” and “Do not X-ray”;

- If it is nevertheless possible that the package might be security checked by X-rays, then a physical dosemeter should be included with the specimen;
- The sample should be packaged and labeled according to national regulations for transport of diagnostic specimens. For international transport, by air, IATA regulations require that the packaging should conform with United Nations Regulation 650 for transporting diagnostic specimens. In brief, the specimen tube(s) must be placed with sufficient absorbent material into a rigid, crush-proof and watertight secondary container. If specimen tubes or secondary containers have screw caps these must be reinforced with adhesive tape. The secondary container should then be placed in rigid outer packaging, e.g. a sturdy cardboard box, with suitable labelling. Some international courier firms do supply special packaging that conforms with the regulation;
- The package itself and the "Nature of Quality of Goods" box of the air waybill should show the wording "Diagnostic specimen packet in compliance with IATA packing instruction 650";
- Immediately after sampling, ship the sample. The sample must be at the laboratory within 24 h of sampling. For international transport, experience has shown that the major courier companies provide the most efficient method with least delay; and
- Contact the laboratory and inform about the transport mode and waybill number. This is important for tracking the sample.

Annex 12: Management of internal contamination

Table A12.1. Some examples of critical organs following radionuclide intake (internal contamination).

Radionuclide	**Critical organ**	**Observations**
Bromium (^{82}Br)	whole body	Monitoring: urine
Calcium (^{45}Ca,^{47}Ca)	bone	Monitoring: urine (^{45}Ca and ^{47}Ca), WBC (^{47}Ca)
Caesium (^{137}Cs)	whole body	Monitoring: urine, faeces, WBC
Chromium (^{51}Cr); Manganese (^{54}Mn)	gastrointestinal tract (Cr), lung (Cr and Mn) and liver (Mn)	Monitoring: urine, WBC
Cobalt (^{57}Co, ^{58}Co, ^{60}Co)	lung (inhalation) and gastrointestinal tract (ingestion)	If only ingestion, parenteral treatment is not necessary (non-soluble, non-absorbable) Monitoring: urine, WBC
Gold (^{198}Au); Copper (Cu)	kidney, liver and gastrointestinal tract.	Monitoring: urine, WBC
Iodine (^{123}I, ^{125}I, ^{131}I)	thyroid	Monitoring: urine, WBC, thyroid monitoring
Iron (^{55}Fe ^{59}Fe)	bone marrow, liver, spleen.	Monitoring: urine, WBC
Mercury (^{197}Hg, ^{203}Hg); Lead (^{210}Pb); Polonium (^{210}Po); Bismuth (Bi); Arsenic (As); Nickel (Ni).	kidney (Hg, Pb, Po), bone (Pb), lung (Po).	Monitoring: urine and WBC (Hg), urine and faeces (Pb, Po)
Phosphorus (^{32}P)	bone	Monitoring: urine
Rare Earths (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu); Plutonium (^{238}Pu, ^{239}Pu, ^{241}Pu) ; Transplutonics (^{241}Am, ^{249}Bk, ^{242}Cm, ^{244}Cm, ^{252}Cf, ^{253}Es); Yttrium (^{89}Y, ^{90}Y); Neptunium (Np); Ruthenium (Ru); Thorium (Th); Zirconium (Zr).	bone, lung (inhalation) and gastrointestinal tract (ingestion) For Yttrium: kidney and gastrointestinal tract	Monitoring: urine, faeces, WBC
Strontium (^{85}Sr, ^{85}Sr, ^{85}Sr); Radium (^{226}Ra)	bone	Monitoring: urine, faeces
Sulphur (^{35}S)	whole body	Monitoring: urine
Tritium (^{3}H)	whole body	Monitoring: urine
Uranium (^{235}U, ^{238}U)	kidney	Monitoring: urine

This list includes some agents for which clinical experience is still limited. The preferred treatment is indicated in the third column. The status of approval of these drugs differs among countries (e.g. some of them are approved by FDA for other purposes or just for adults, other drugs are not approved by FDA but they are commercially available in the EC).

Table A12.2. Examples of the possible therapeutic agents to be used for treatment of radionuclide intake (internal contamination).

Radionuclide	**Possible therapeutic agents**	**Preferred treatment**
Arsenic (As)	Dimercaptopropansulphonate (DMPS) Alternative: dimercaprol (BAL) Penicillamine Dimercapto succinic acid (Succimer/DMSA)	DMPS Alternative: BAL
Barium (^{140}Ba)	See strontium	See strontium
Bismuth (Bi)	Dimercaptopropansulphonate (DMPS) Dimercapto succinic acid (Succimer/DMSA) Penicillamine Alternative: dimercaprol (BAL)	DMPS Alternative: BAL
Bromium (^{82} Br)	Water (hyperhydration) Diuretics	Water (hyperhydration)
Calcium (^{45}Ca, ^{47} Ca)	See strontium	See strontium
Cesium (^{137}Cs)	Ferric ferrocyanide (Prussian blue)	Ferric ferrocyanide (Prussian blue)
Chromium (^{51}Cr)	DTPA Dimercapto succinic acid (Succimer/DMSA) Dimercaptopropansulphonate (DMPS) Alternatives: Desferoxamine/BAL	Succimer (DMSA)
Cobalt (^{57}Co, ^{58}Co, ^{60}Co)	DTPA Cobalt EDTA Cobalt gluconate Penicillamine BAL	Cobalt EDTA
Copper (Cu)	Penicillamine Dimercapto succinic acid (Succimer/DMSA) Dimercaptopropansulphonate (DMPS) Alternative: dimercaprol (BAL)	Penicillamine
Gold (^{198}Au)	Penicillamine Dimercaptopropansulphonate (DMPS) Alternative: dimercaprol (BAL)	DMPS Alternative: BAL
Iodine (^{123}I, ^{125}I, ^{131}I)	Potassium iodide Potassium iodate	Potassium iodine
Iron (^{55}Fe, ^{59} Fe)	Desferoxamine (DFOA) Alternative: DTPA and EDTA	DFOA
Lead (^{210} Pb)	Dimercapto succinic acid (Succimer/DMSA) Dimercaptopropansulphonate (DMPS) Alternative: dimercaprol (BAL) with EDTA	Succimer (DMSA)

Manganese (^{54}Mn)	EDTA DTPA Alternatives: Desferoxamine/BAL	EDTA
Mercury (^{197}Hg, ^{203}Hg)	Dimercaptopropansulphonate (DMPS) Alternative: dimercaprol (BAL) EDTA Penicillamine Dimercapto succinic acid (Succimer/DMSA)	DMPS Alternative: BAL
Neptunium (Np)	Dimercaptopropansulphonate (DMPS) Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA DTPA + DFOA
Nickel (Ni)	Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA
Phosphorus (^{32}P)	Sodium phosphate/Potassium phosphate Aluminium hydroxide/aluminium phosphate Calcium	Sodium phosphate/ Potassium phosphate Aluminium hydroxide/ aluminium phosphate
Plutonium (^{238}Pu, ^{239}Pu, ^{241}Pu)	Trisodium diethylenetriamine pentaacetate (DTPA) EDTA DFOA	DTPA
Polonium (^{210}Po)	Dimercaptopropansulphonate (DMPS) Alternative: dimercaprol (BAL) Penicillamine Dimercapto succinic acid (Succimer/DMSA)	DMPS Alternative: BAL
Radium (^{226}Ra)	See Strontium	See strontium
Rare Earths (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu)	Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA
Rubidium (Rb)	Ferric ferrocyanide (Prussian blue) Potassium bicarbonate	Ferric ferrocyanide (Prussian blue)
Ruthenium (Ru)	Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA
Strontium (^{85}Sr, ^{85}Sr, ^{85}Sr)	Classic regime: - Aluminium phosphate/Aluminium hydroxide - Barium sulphate Alternate regime: - Sodium or calcium alginate - Ammonium chloride - Calcium gluconate/Calcium phosphate Other regime on: Strontium lactate or gluconate Potassium or sodium rodhizonate (only externally for wounds contaminated with Sr)	Alternate regime: - Sodium or calcium alginate - Ammonium chloride - Calcium gluconate/ Calcium phosphate Potassium or sodium rodhizonate (only externally for wounds contaminated with Sr)
Sulphur (^{35}S)	Sodium thiosulphate	Sodium thiosulphate

Thallium (^{201}Tl)	Ferric ferrocyanide (Prussian blue)	Ferric ferrocyanide (Prussian blue)
Thorium (Th)	Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA
Transplutoniucs (^{241}Am, ^{249}Bk, ^{242}Cm, ^{244}Cm, ^{252}Cf, ^{253}Es)	Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA
Tritium (^{3}H)	Water (hyperhydration)	Water (hyperhydration)
Uranium (^{235}U, ^{238}U)	Sodium bicarbonate	Sodium bicarbonate
Yttrium (^{89}Y, ^{90}Y)	Trisodium diethylenetriamine pentaacetate (DTPA) EDTA	DTPA
Zirconium (Zr)	Trisodium diethylenetriamine pentaacetate (DTPA)	DTPA

Table A12.3. Recommended protocols for treatment of internal radionuclide contamination. OA: oral administration; IV: intravenous; IM: intramuscular; WBC: whole body count; GI: gastro-intestinal.

Therapeutic Agent	**Therapeutic Scheme**	**Action**	**Contra-indications**	**Precautions**
Aluminium hydroxide (Aludrox®)	OA 100 ml/day, 3 times/ day aluminium hydroxide gel.	Reduction of intestinal absorption	Renal failure	Risk of aluminium toxicity (avoid long-term use)
Aluminium phosphate (Phosphaluge®)	OA 50 mg/day frist day and 20-30 mg /days the following days	Reduction of intestinal absorption		
Ammonium chloride	OA 6 g ammonium chloride daily in 3 divided doses	Increase of the excretion rate	Metabolic acidosis, uric lithiasis, renal or liver failure.	
Barium sulphate e.g. Micropaque®	OA 100-300 g barium sulphate aqueous suspension in single dose.	Reduced absorption	Known or suspected colonic obstruction, acute GI hemorrhage, inflammation and perforation, hypersensitivity to barium sulphate preparations.	May lead to constipation
British Anti-Lewisite (BAL)/ Dimercaprol	BAL 2.5 mg/kg deep IM injection 4 times per day for two days, then twice per day during the third day and thereafter, once daily for 5-10 days.	Chelation	Hepatic insufficiency, preexisting kidney disease, hypertension and current use of medicinal iron. Production of alkaline urine affords protection to the kidney. Since the drug is presented in a peanut oil suspension, peanut allergy is a contra-indication.	BAL is toxic and it is seldom the first drug of choice. First test for peanut hypersensitivity (with 0.25 amp.). Pregnancy category C. BAL IM may cause sterile abscess.
Calcium gluconate	Calcium gluconate 10 % in 500 ml normal saline solution or dextrose solution IV slowly or OA of 10 g powder in a 30 cc vial, add water and drink.	Isotopic dilution	Renal failure,	Monitor blood pressure during infusion; caution advised in renal impairment.
Cobalt ethylen-ediamine tetraacetate (Co-EDTA) e.g. Kelocyanor®	Slow IV administration of 300-600 mg/ 40 ml of Co-EDTA solution followed by hypertonic glucose solution (50 ml) to prevent cobalt toxicity.	Chelation	Hypersensitivity (anaphylactic reactions have been described).	Control blood pressure during Co-EDTA infusion. Pregnancy category C.

Cobalt gluconate e.g Cobal Oligosol Labcatal®	Cobalt gluconate 0.9 mg sublingual (2 amp of 0.45 mg in 2 ml)	Isotopic dilution Reduction of the resorption rate		
Colloidal aluminium phosphate e.g Phosphalugel®	OA 5 packages (2.5 g each package) immediately after exposure (single dose).	Reduced absorption		May lead to constipation
Desferoxamine (DFOA)	Desferoxamine (DFOA) starting with 1 g IM (preferred) or IV in 250 normal saline or dextrose solution. Repeat as indicated as 500 mg every 4 hours for 2 more doses. Then, 500 mg every 12 hours for 3 days. Following days (if necessary) 500 mg/day. Contaminated wounds: washing with DFOA 10 % DFOA combined with Ca-DTPA is more effective than DFOA alone.	Enhancement of excretion rate and reduced absorption.	Anuria, severe renal disease.	Rapid infusion may lead to hypotension and shock. Pregnancy category C.
Dimercapto propansulphonate (DMPS) e.g Dimaval® Heyl	OA 1.2 to 2.4 g/day DMPS (300 mg 4 to 8 times a day).	Chelation	DMPS allergy, severe renal disease.	Analogue of BAL, more used in Europe and Asia (not FDA approved for chelation). Monitor renal function.
Dimercapto succinic acid (DMSA) / Succimer e.g. Chemet® and Succicaptal®	Pediatric dosing approved by FDA for treatment of lead poisoning in children as OA 10 mg/kg or 350 mg/m^2 every 8 hours for 5 days. Following 2 weeks one dose every 12 hours (i.e. one total course of treatment lasts 19 days). Repeated courses may be necessary if indicated by monitoring of the efficacy of treatment.	Chelation and increase of urinary excretion	DMSA allergy, preexisting kidney or liver disease. DMSA is not used in conjunction with ETDA or penicillamine.	DMSA is less toxic than BAL, it has fewer and milder side effects (FDA approved for chelation) . Hydration is essential. Pregnancy category C.
Edetate calcium disodium (Ca-EDTA)	1 g/m^2/d added to 500 ml 5 % dextrose or normal saline solution IV infused over 8-12 hours or IM 1 g EDTA injection (200 mg/ml total 5 ml). Administer once as above, unless indicated for extended treatment.	Chelation	Anuria, active renal disease, hepatitis	Monitor renal and heart function. Pregnancy category B.

Penicillamine e.g. Cuprimine® and Metalcaptase®	OA penicillamine 250-500 mg every 8 hours Duration indicated by the bioassays (and according to the magnitude of the incident)	Chelation	Penicillin allergy Pregnancy is considered a contraindication for this drug unless Wilson's disease or cystinuria (pregnancy category D)[2]	High incidence of adverse reactions (e.g nephritic syndrome, thrombocytopenia, optic neuropathy). Patients should be under close medical supervision during the treatment.
Potassium iodide (KI) (130 mg potassium iodide contains 100 mg of stable iodine)	For adolescents and adults, including pregnant and breast feeding women: OA 130 mg/day KI single dose immediately before or promptly after the intake. The efficacy decrease with time after exposure. Children 3-12 years-old: 65 mg; 1 month to 3 years-old: 32 mg; under 1 month: 16 mg. In scenarios where the risk of incorporation continues, the treatment may continue during 7 days. Avoid repeting administration of KI in neonates, pregnant and lactating women.	Isotopic dilution and thyroid blocking (saturation with stable iodine)	Iodine hypersensitivity[3].	Cautious use in case of history of thyroid disease, dermatitis herpetiformis, hypocomplementemic vasculitis. Transient hypothyroidism may develop in neonates following KI administration (perform TSH measurements).
Potassium or sodium rodhizonate (powder)	Wounds contaminated with strontium: spread 1g rodhizonate powder	Reduction of the resorption rate		
Prussian blue (PB) /ferric ferrocyanide e.g. Radiogardase®	Adults and adolescents: OA 3g/day PB in 3 divided doses (minimun of 2 h between consecutive administration). In highly contaminated adults the dose may be scaled up to 10-12 g/day. Children: OA 1-1.5 g/day PB in 2-3 divided doses. Infants (< 2 y)[4]: OA 0.2 - 0.3 mg/kg PB Continue for a minimum of 4 weeks.	Inhibits enterohepatic cycle and increases fecal excretion.		Monitor serum electrolytes and evaluate liver function (PB is less effective in patients with impaired liver function). Use with caution in patients with history of GI obstruction (PB is constipating) and/or peptic ulcer disease. Pregnancy category C[5]

Sodium bicarbonate	Slow IV infusion of 250 mL isotonic 1.4 % sodium bicarbonate. Continue over the following days according to the seriousness of contamination (around 3 days). Alternative: OA of 1g bicarbonate every 4 hours until the urine reaches a pH 7-8. Contaminated wounds: wash with isotonic 1.4 % solution of sodium bicarbonate	Alkal-inisation of urine; reduced risk of acute tubular necrosis	Sodium retention and congestive heart failure.	Control blood pH, electrolytes and renal function. Sodium bicarbo-nate may aggravate hypokalaemia. Monitor urine pH and electrolytes.
Sodium or calcium alginate e.g. Gaviscon®	OA 10g alginate aqueous suspension_	Reduced intestinal absorption	Sodium retention and congestive heart failure.	
Sodium thiosulphate	Single dose OA 1g	Isotopic dilution	Sodium retention and congestive heart failure.	
Sodium/ potassium phosphate	OA 1g sodium or potas-sium phosphate (the following days 0.5g)	Isotopic dilution	Renal failure: avoid sodium phosphate; cardiac insuf-ficiency: avoid potassium phosphate.	
Strontium gluconate	After absorption but shortly after exposure to strontium, 600 mg daily in slow IV perfusion for up to 6 days.	Isotopic dilution		
Strontium lactate	After absorption but shortly after exposure to strontium OA 0.5-1.5 g/ day for several weeks.	Isotopic dilution		

Trisodium diethylenetri-amine pentaac-etate (DTPA)	IV administration of 1g DTPA in 250 ml normal saline solution/ 5 % glucose or Ringer lactate in 30 minutes or 1g DTPA as undiluted 25 % solution in slow IV push over 3 to 4 minutes. Use Ca-DTPA the first day (or during the first few days), then for maintenance change to Zn-DTPA daily up to 5 days, if bioassay results indicate need for additional chelation. In children < 12 y start with Ca-DTPA first dose (14 mg/kg IV as above, n ever exceed 1 g/day) and then change to Zn-DTPA. Inhalation: nebulize with 4 ml Ca-DTPA 25 % solution dilutedr 1:1 with sterile water or normal saline solution or inhalation of micronized Ca-DTPA. Wounds: washing with Ca-DTPA 25 % solution.	Chelation	DTPA is contraindi-cated in patiens with bone marrow depression, nephritic syn-drome, renal insufficiency, and/ or renal failure.	Control blood pressure during DTPA infusion. Treatment of pregnant women should begin and continue with Zn-DTPA (preg-nancy category B[6]) instead of Ca-DTPA (pregnancy category C). Although DTPA may be effective for uranium decorporation if given within 4 hours after intake, it should not be used since it could cause uranium precipitation in the renal tubules.
Water diuresis	OA 3-4 liters/day (including water, fruit juice, tea, coffee, beer). May be increased to 6-10 litres/day in severe contaminations. May be performed through IV administration of up to 3 litres /day 5 % glucose in water or saline (only if fluids cannot be given orally). Duration of treatment: 5 days	Isotopic dilution Enhance-ment of excretion	Congestive heart failure	Usually forced to the tolerance level by patient. Monitor electrolyte balance (sodium and potassium).

2 Pregnancy category D: there is positive evidence of human fetal risk, but the benefits from use in pregnant women may be acceptable despite the risk (e.g. if the drug is needed in a life-threatening situation or for a serious disease for which safer drugs cannot be used or are ineffective).

3 In case of hypersensitivity to iodine, thyroid blocking may be induced by OA of 200 mg potassium perchlorate 3 times daily.

4 Limited clinical experience, not approved by the FDA

5 Pregnancy category C: either studies in animals have revealed adverse effects on the fetus (teratogenic or embryocidal or other) and there are no controlled studies in women, or studies in

women and animals are not available. Drugs should be given only if the potential benefit justifies the potential risk to the fetus.

6 Pregnancy category B: either animal reproduction studies have not demonstrated a fetal risk but there are no controlled studies in pregnant women, or animal reproduction studies have shown an adverse effect (other than a decrease in fertility) that was not confirmed in controlled studies in women in the first trimester (and there is no evidence of a risk in later trimesters).

Annex 13: Look-up tables for the assessment of internal doses

This Annex presents tables that allow committed effective doses and absorbed doses to organs to be calculated from measurements of bioassay quantities at specified times after an intake by inhalation or ingestion. The use of these tables is described in Section H.5.1.

Calculations were performed using the ICRP Publication 66 Respiratory Tract Model, the current biokinetic models described in ICRP Publications 30, 56, 67 and 69, and the ICRP Publication 30 gastro-intestinal tract model. Respiratory tract deposition calculations were made using the default physical activity levels given in ICRP Publication 71, and the occupational exposure defaults for particle size parameters (including an Activity Median Aerodynamic Diameter of 5 µm). All calculations were performed for adults.

Data is presented only for measurements made with the primary monitoring methods listed in Annex 10, Table A10.1. In some cases, there could be a need to assess doses from measurements made with a method other than the primary monitoring method. The most likely case would be where lung measurements are recommended here, but whole body measurements are carried out. (An example is the assessment of doses from intakes by inhalation of ^{60}Co). In such cases, doses can be assessed from the data in the tables in Annex 10, using the fact that the data presented corresponds to a committed effective dose of 200 mSv.

Data is presented to allow interpretation of whole body measurements of the actinides ^{238}Pu, ^{241}Am and ^{252}Cf, for intakes by ingestion. This technique would not normally be recommended for assessments of internal doses from occupational exposures. However, whole body monitoring could have adequate sensitivity for assessment of doses where deterministic levels could be approached, and has the advantage that results could be obtained rapidly. It is likely that the technique would need development by the measurement laboratory. Urine measurements would have much better sensitivity, but may be subject to high uncertainties (+/- an order of magnitude is typical) and could require several days or even weeks before results could be obtained. Where intakes could be relatively high, both techniques should ideally be employed.

Note that the data presented here should not be used for the assessment of internal doses after treatment to reduce doses has been employed (e.g. administration of stable iodine, treatment with Prussian Blue or with DTPA). In such circumstances, expert advice must be sought.

Table A13.1a. Doses from an intake by INHALATION of ^{54}Mn (ABSORPTION TYPE F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		5.0E-10	9.5E-10	1.1E-09	1.6E-09
12 h	1.51		5.5E-10	1.0E-09	1.2E-09	1.7E-09
1 d	1.84		6.6E-10	1.3E-09	1.4E-09	2.1E-09
2 d	2.57		9.3E-10	1.8E-09	2.0E-09	3.0E-09
3 d	3.18		1.1E-09	2.2E-09	2.5E-09	3.7E-09
4 d	3.61		1.3E-09	2.5E-09	2.8E-09	4.2E-09
5 d	3.92		1.4E-09	2.7E-09	3.1E-09	4.5E-09
6 d	4.17		1.5E-09	2.9E-09	3.2E-09	4.8E-09
7 d	4.38		1.6E-09	3.0E-09	3.4E-09	5.0E-09
10 d	4.93		1.8E-09	3.4E-09	3.8E-09	5.7E-09
14 d	5.59		2.0E-09	3.9E-09	4.4E-09	6.4E-09
21 d	6.66		2.4E-09	4.6E-09	5.2E-09	7.7E-09
28 d	7.74		2.8E-09	5.3E-09	6.0E-09	8.9E-09

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.1b. Doses from an intake by INHALATION of ^{54}Mn (ABSORPTION TYPE M) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	13.1		1.4E-08	4.3E-09	9.6E-09	1.7E-08
12 h	13.8		1.5E-08	4.5E-09	1.0E-08	1.8E-08
1 d	14.4		1.5E-08	4.7E-09	1.1E-08	1.9E-08
2 d	14.9		1.6E-08	4.8E-09	1.1E-08	1.9E-08
3 d	15.1		1.6E-08	4.9E-09	1.1E-08	2.0E-08
4 d	15.4		1.6E-08	5.0E-09	1.1E-08	2.0E-08
5 d	15.7		1.7E-08	5.1E-09	1.1E-08	2.0E-08
6 d	15.9		1.7E-08	5.2E-09	1.2E-08	2.1E-08
7 d	16.2		1.7E-08	5.3E-09	1.2E-08	2.1E-08
10 d	17.0		1.8E-08	5.5E-09	1.2E-08	2.2E-08
14 d	18.2		1.9E-08	5.9E-09	1.3E-08	2.3E-08
21 d	20.2		2.1E-08	6.6E-09	1.5E-08	2.6E-08
28 d	22.4		2.4E-08	7.3E-09	1.6E-08	2.9E-08

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 µm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor ([Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.1c. Doses from an intake by INGESTION of ^{54}Mn (f_1 = 0.1) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		1.3E-10	3.6E-10	1.7E-09	7.2E-10
12 h	1.07		1.3E-10	3.8E-10	1.8E-09	7.6E-10
1 d	1.36		1.7E-10	4.8E-10	2.3E-09	9.6E-10
2 d	2.60		3.3E-10	9.3E-10	4.3E-09	1.8E-09
3 d	4.87		6.1E-10	1.7E-09	8.1E-09	3.4E-09
4 d	7.74		9.7E-10	2.7E-09	1.3E-08	5.5E-09
5 d	10.3		1.3E-09	3.6E-09	1.7E-08	7.3E-09
6 d	12.0		1.5E-09	4.3E-09	2.0E-08	8.5E-09
7 d	13.1		1.6E-09	4.7E-09	2.2E-08	9.3E-09
10 d	15.2		1.9E-09	5.4E-09	2.5E-08	1.1E-08
14 d	17.3		2.2E-09	6.1E-09	2.9E-08	1.2E-08
21 d	20.6		2.6E-09	7.3E-09	3.4E-08	1.5E-08
28 d	23.9		3.0E-09	8.5E-09	4.0E-08	1.7E-08

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.2a. Doses from an intake by INHALATION of ^{60}Co (Absorption Type M) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	13.1		2.2E-07	8.0E-09	3.8E-08	1.1E-07
12 h	13.8		2.3E-07	8.4E-09	4.0E-08	1.1E-07
1 d	14.3		2.4E-07	8.7E-09	4.2E-08	1.1E-07
2 d	14.8		2.5E-07	9.0E-09	4.3E-08	1.2E-07
3 d	15.1		2.5E-07	9.2E-09	4.4E-08	1.2E-07
4 d	15.3		2.6E-07	9.3E-09	4.4E-08	1.2E-07
5 d	15.5		2.6E-07	9.5E-09	4.5E-08	1.2E-07
6 d	15.8		2.7E-07	9.6E-09	4.6E-08	1.3E-07
7 d	16.0		2.7E-07	9.8E-09	4.7E-08	1.3E-07
10 d	16.7		2.8E-07	1.0E-08	4.9E-08	1.3E-07
14 d	17.7		3.0E-07	1.1E-08	5.1E-08	1.4E-07
21 d	19.4		3.3E-07	1.2E-08	5.6E-08	1.6E-07
28 d	21.2		3.6E-07	1.3E-08	6.2E-08	1.7E-07

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.2b. Doses from an intake by INHALATION of ^{60}Co (Absorption Type S) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	11.8		2.3E-07	7.1E-09	3.7E-08	2.3E-07
12 h	12.4		2.5E-07	7.4E-09	3.8E-08	2.4E-07
1 d	12.9		2.6E-07	7.7E-09	4.0E-08	2.5E-07
2 d	13.2		2.6E-07	7.9E-09	4.1E-08	2.6E-07
3 d	13.4		2.7E-07	8.0E-09	4.1E-08	2.6E-07
4 d	13.5		2.7E-07	8.1E-09	4.2E-08	2.6E-07
5 d	13.7		2.7E-07	8.2E-09	4.2E-08	2.7E-07
6 d	13.8		2.7E-07	8.2E-09	4.3E-08	2.7E-07
7 d	13.9		2.8E-07	8.3E-09	4.3E-08	2.7E-07
10 d	14.3		2.8E-07	8.6E-09	4.4E-08	2.8E-07
14 d	14.9		3.0E-07	8.9E-09	4.6E-08	2.9E-07
21 d	15.8		3.1E-07	9.4E-09	4.9E-08	3.1E-07
28 d	16.7		3.3E-07	1.0E-08	5.2E-08	3.3E-07

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: S
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.2c. Doses from an intake by INGESTION of ^{60}Co (f_1 = 0.1) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ :	Lungs	Red bone marrow	Colon	-
		Integration period :	30 d			To age 70 y
Measurement time						
6 h	1.01		2.1E-10	5.8E-10	7.0E-09	3.4E-09
12 h	1.09		2.2E-10	6.2E-10	7.5E-09	3.7E-09
1 d	1.41		2.9E-10	8.0E-10	9.8E-09	4.8E-09
2 d	2.89		6.0E-10	1.7E-09	2.0E-08	9.8E-09
3 d	6.13		1.3E-09	3.5E-09	4.2E-08	2.1E-08
4 d	11.5		2.4E-09	6.6E-09	8.0E-08	3.9E-08
5 d	17.9		3.7E-09	1.0E-08	1.2E-07	6.1E-08
6 d	23.3		4.8E-09	1.3E-08	1.6E-07	7.9E-08
7 d	27.0		5.6E-09	1.5E-08	1.9E-07	9.2E-08
10 d	33.4		6.9E-09	1.9E-08	2.3E-07	1.1E-07
14 d	39.6		8.2E-09	2.3E-08	2.7E-07	1.3E-07
21 d	48.3		1.0E-08	2.8E-08	3.3E-07	1.6E-07
28 d	54.7		1.1E-08	3.1E-08	3.8E-07	1.9E-07

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.3a. Doses from an intake by INHALATION of ^{75}Se (Absorption Type F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		4.8E-10	4.4E-10	6.1E-10	2.0E-09
12 h	1.49		5.2E-10	4.8E-10	6.7E-10	2.1E-09
1 d	1.73		6.0E-10	5.6E-10	7.7E-10	2.5E-09
2 d	2.09		7.3E-10	6.8E-10	9.3E-10	3.0E-09
3 d	2.32		8.1E-10	7.5E-10	1.0E-09	3.3E-09
4 d	2.46		8.6E-10	7.9E-10	1.1E-09	3.5E-09
5 d	2.56		8.9E-10	8.3E-10	1.1E-09	3.7E-09
6 d	2.64		9.2E-10	8.5E-10	1.2E-09	3.8E-09
7 d	2.71		9.5E-10	8.7E-10	1.2E-09	3.9E-09
10 d	2.90		1.0E-09	9.3E-10	1.3E-09	4.1E-09
14 d	3.13		1.1E-09	1.0E-09	1.4E-09	4.5E-09
21 d	3.53		1.2E-09	1.1E-09	1.6E-09	5.0E-09
28 d	3.94		1.4E-09	1.3E-09	1.8E-09	5.6E-09

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.3b. Doses from an intake by INHALATION of ^{75}Se (Absorption Type M) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole Body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period :	30 d			To age 70 y
Measurement time						
6 h	1.37		2.9E-09	4.2E-10	5.7E-10	2.4E-09
12 h	1.50		3.2E-09	4.6E-10	6.2E-10	2.6E-09
1 d	1.76		3.8E-09	5.4E-10	7.3E-10	3.1E-09
2 d	2.19		4.7E-09	6.7E-10	9.1E-10	3.8E-09
3 d	2.47		5.3E-09	7.5E-10	1.0E-09	4.3E-09
4 d	2.64		5.7E-09	8.0E-10	1.1E-09	4.6E-09
5 d	2.74		5.9E-09	8.4E-10	1.1E-09	4.8E-09
6 d	2.82		6.1E-09	8.6E-10	1.2E-09	4.9E-09
7 d	2.89		6.2E-09	8.8E-10	1.2E-09	5.0E-09
10 d	3.07		6.6E-09	9.4E-10	1.3E-09	5.3E-09
14 d	3.29		7.1E-09	1.0E-09	1.4E-09	5.7E-09
21 d	3.67		7.9E-09	1.1E-09	1.5E-09	6.4E-09
28 d	4.07		8.7E-09	1.2E-09	1.7E-09	7.1E-09

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.3c. Doses from an intake by INGESTION of ^{75}Se (f_1 = 0.8) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period :	30 d			To age 70 y
Measurement time						
6 h	1.01		6.2E-10	5.8E-10	9.7E-10	2.6E-09
12 h	1.03		6.3E-10	6.0E-10	9.9E-10	2.7E-09
1 d	1.09		6.7E-10	6.3E-10	1.1E-09	2.8E-09
2 d	1.22		7.4E-10	7.1E-10	1.2E-09	3.2E-09
3 d	1.31		8.0E-10	7.6E-10	1.3E-09	3.4E-09
4 d	1.38		8.4E-10	8.0E-10	1.3E-09	3.6E-09
5 d	1.43		8.7E-10	8.2E-10	1.4E-09	3.7E-09
6 d	1.47		9.0E-10	8.5E-10	1.4E-09	3.8E-09
7 d	1.51		9.2E-10	8.7E-10	1.5E-09	3.9E-09
10 d	1.61		9.8E-10	9.3E-10	1.6E-09	4.2E-09
14 d	1.74		1.1E-09	1.0E-09	1.7E-09	4.5E-09
21 d	1.96		1.2E-09	1.1E-09	1.9E-09	5.1E-09
28 d	2.19		1.3E-09	1.3E-09	2.1E-09	5.7E-09

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.4a. Doses from an intake by INHALATION of ^{90}Sr (Absorption Type F) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	14.3		5.5E-09	6.7E-08	5.4E-08	4.4E-07
2 d	41.8		1.6E-08	1.9E-07	1.6E-07	1.3E-06
3 d	62.6		2.4E-08	2.9E-07	2.4E-07	1.9E-06
4 d	83.8		3.2E-08	3.9E-07	3.2E-07	2.6E-06
5 d	106		4.0E-08	4.9E-07	4.0E-07	3.3E-06
6 d	130		4.9E-08	6.0E-07	4.9E-07	4.0E-06
7 d	155		5.9E-08	7.2E-07	5.9E-07	4.8E-06
10 d	236		9.0E-08	1.1E-06	9.0E-07	7.3E-06
14 d	348		1.3E-07	1.6E-06	1.3E-06	1.1E-05
21 d	579		2.2E-07	2.7E-06	2.2E-06	1.8E-05
28 d	906		3.5E-07	4.2E-06	3.4E-06	2.8E-05

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.4b. Doses from an intake by INHALATION of ^{90}Sr (Absorption Type S) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ :	Lungs	Red bone marrow	Colon	-
		Integration period :	30 d			To age 70 y
Measurement time						
1 d	1,270		6.7E-05	7.8E-08	8.4E-06	1.2E-04
2 d	2,960		1.6E-04	1.8E-07	2.0E-05	2.7E-04
3 d	4,590		2.4E-04	2.8E-07	3.0E-05	4.3E-04
4 d	6,180		3.3E-04	3.8E-07	4.1E-05	5.7E-04
5 d	7,810		4.1E-04	4.8E-07	5.2E-05	7.2E-04
6 d	9,500		5.0E-04	5.8E-07	6.3E-05	8.8E-04
7 d	11,200		5.9E-04	6.9E-07	7.4E-05	1.0E-03
10 d	16,600		8.7E-04	1.0E-06	1.1E-04	1.5E-03
14 d	23,300		1.2E-03	1.4E-06	1.5E-04	2.2E-03
21 d	35,300		1.9E-03	2.2E-06	2.3E-04	3.3E-03
28 d	49400		2.6E-03	3.0E-06	3.3E-04	4.6E-03

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: S
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.4c. Doses from an intake by INGESTION of ^{90}Sr (f_1 = 0.3) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period :	30 d			To age 70 y
Measurement time						
1 d	17.7		5.4E-09	7.1E-08	2.1E-07	4.9E-07
2 d	45.5		1.4E-08	1.8E-07	5.4E-07	1.3E-06
3 d	69.7		2.1E-08	2.8E-07	8.3E-07	1.9E-06
4 d	94.3		2.9E-08	3.8E-07	1.1E-06	2.6E-06
5 d	120		3.7E-08	4.8E-07	1.4E-06	3.3E-06
6 d	147		4.5E-08	5.9E-07	1.7E-06	4.1E-06
7 d	176		5.4E-08	7.1E-07	2.1E-06	4.9E-06
10 d	270		8.2E-08	1.1E-06	3.2E-06	7.5E-06
14 d	401		1.2E-07	1.6E-06	4.7E-06	1.1E-05
21 d	668		2.0E-07	2.7E-06	7.9E-06	1.8E-05
28 d	1050		3.2E-07	4.2E-06	1.2E-05	2.9E-05

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.5a. Doses from an intake by INHALATION of ^{110m}Ag (Absorption Type F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		2.4E-09	2.0E-09	5.0E-09	9.4E-09
12 h	1.51		2.7E-09	2.2E-09	5.5E-09	1.0E-08
1 d	1.83		3.2E-09	2.6E-09	6.6E-09	1.3E-08
2 d	2.52		4.5E-09	3.6E-09	9.1E-09	1.7E-08
3 d	3.06		5.4E-09	4.4E-09	1.1E-08	2.1E-08
4 d	3.39		6.0E-09	4.9E-09	1.2E-08	2.3E-08
5 d	3.59		6.4E-09	5.2E-09	1.3E-08	2.5E-08
6 d	3.73		6.6E-09	5.4E-09	1.4E-08	2.6E-08
7 d	3.83		6.8E-09	5.5E-09	1.4E-08	2.6E-08
10 d	4.10		7.3E-09	5.9E-09	1.5E-08	2.8E-08
14 d	4.41		7.8E-09	6.4E-09	1.6E-08	3.0E-08
21 d	4.94		8.8E-09	7.1E-09	1.8E-08	3.4E-08
28 d	5.50		9.7E-09	7.9E-09	2.0E-08	3.8E-08

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.5b. Doses from an intake by INGESTION of ^{110m}Ag (f_1 = 0.05) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		3.4E-10	7.3E-10	7.9E-09	2.8E-09
12 h	1.08		3.6E-10	7.7E-10	8.4E-09	3.0E-09
1 d	1.38		4.6E-10	9.9E-10	1.1E-08	3.8E-09
2 d	2.80		9.4E-10	2.0E-09	2.2E-08	7.8E-09
3 d	5.85		2.0E-09	4.2E-09	4.6E-08	1.6E-08
4 d	10.7		3.6E-09	7.7E-09	8.3E-08	3.0E-08
5 d	15.9		5.3E-09	1.1E-08	1.2E-07	4.4E-08
6 d	19.7		6.6E-09	1.4E-08	1.5E-07	5.4E-08
7 d	21.9		7.3E-09	1.6E-08	1.7E-07	6.1E-08
10 d	24.5		8.2E-09	1.8E-08	1.9E-07	6.8E-08
14 d	26.5		8.9E-09	1.9E-08	2.1E-07	7.3E-08
21 d	29.6		9.9E-09	2.1E-08	2.3E-07	8.2E-08
28 d	33.0		1.1E-08	2.4E-08	2.6E-07	9.1E-08

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.6a. Doses from an intake by INHALATION of ^{109}Cd (Absorption Type F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		1.6E-10	1.0E-10	8.3E-10	1.4E-08
12 h	1.51		1.7E-10	1.1E-10	9.1E-10	1.5E-08
1 d	1.82		2.1E-10	1.4E-10	1.1E-09	1.8E-08
2 d	2.48		2.8E-10	1.9E-10	1.5E-09	2.5E-08
3 d	2.95		3.4E-10	2.2E-10	1.8E-09	2.9E-08
4 d	3.19		3.6E-10	2.4E-10	1.9E-09	3.2E-08
5 d	3.29		3.7E-10	2.5E-10	2.0E-09	3.3E-08
6 d	3.33		3.8E-10	2.5E-10	2.0E-09	3.3E-08
7 d	3.35		3.8E-10	2.5E-10	2.0E-09	3.3E-08
10 d	3.38		3.8E-10	2.5E-10	2.0E-09	3.4E-08
14 d	3.40		3.9E-10	2.5E-10	2.1E-09	3.4E-08
21 d	3.44		3.9E-10	2.6E-10	2.1E-09	3.4E-08
28 d	3.47		4.0E-10	2.6E-10	2.1E-09	3.4E-08

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.6b. Doses from an intake by INGESTION of ^{109}Cd (f_1 = 0.05) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		1.5E-11	1.6E-11	2.8E-09	2.0E-09
12 h	1.07		1.6E-11	1.7E-11	3.0E-09	2.1E-09
1 d	1.38		2.1E-11	2.1E-11	3.8E-09	2.7E-09
2 d	2.79		4.2E-11	4.3E-11	7.7E-09	5.6E-09
3 d	5.78		8.8E-11	9.0E-11	1.6E-08	1.2E-08
4 d	10.4		1.6E-10	1.6E-10	2.8E-08	2.1E-08
5 d	14.9		2.3E-10	2.3E-10	4.1E-08	3.0E-08
6 d	17.9		2.7E-10	2.8E-10	4.9E-08	3.6E-08
7 d	19.3		2.9E-10	3.0E-10	5.3E-08	3.8E-08
10 d	20.3		3.1E-10	3.2E-10	5.6E-08	4.0E-08
14 d	20.4		3.1E-10	3.2E-10	5.6E-08	4.1E-08
21 d	20.7		3.1E-10	3.2E-10	5.7E-08	4.1E-08
28 d	20.9		3.2E-10	3.2E-10	5.7E-08	4.2E-08

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.7a. Doses from an intake by INHALATION of ^{131}I (Absorption Type F) corresponding to a measurement of 1 Bq in THYROID at specified times after a single intake.

Measured quantity: Thyroid	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:			Thyroid	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	18.9				7.4E-07	2.0E-07
12 h	11.0				4.3E-07	1.2E-07
1 d	8.31				3.3E-07	8.8E-08
2 d	8.35				3.3E-07	8.9E-08
3 d	9.13				3.6E-07	9.7E-08
4 d	10.0				3.9E-07	1.1E-07
5 d	11.0				4.3E-07	1.2E-07
6 d	12.1				4.8E-07	1.3E-07
7 d	13.3				5.2E-07	1.4E-07
10 d	17.7				6.9E-07	1.9E-07
14 d	25.7				1.0E-06	2.7E-07
21 d	49.5				1.9E-06	5.2E-07
28 d	95.0				3.7E-06	1.0E-06

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Thyroid
(IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.7b. Doses from an intake by INGESTION of ^{131}I (f_1 = 1) corresponding to a measurement of 1 Bq in THYROID at specified times after a single intake.

Measured quantity: Thyroid	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:			Thyroid	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	16.7				1.3E-06	3.6E-07
12 h	6.56				5.3E-07	1.4E-07
1 d	4.19				3.4E-07	9.0E-08
2 d	4.04				3.3E-07	8.7E-08
3 d	4.41				3.5E-07	9.5E-08
4 d	4.85				3.9E-07	1.0E-07
5 d	5.33				4.3E-07	1.2E-07
6 d	5.85				4.7E-07	1.3E-07
7 d	6.43				5.2E-07	1.4E-07
10 d	8.53				6.9E-07	1.8E-07
14 d	12.4				1.0E-06	2.7E-07
21 d	23.9				1.9E-06	5.2E-07
28 d	45.9				3.7E-06	9.9E-07

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Thyroid
(IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.8a. Doses from an intake by INHALATION of ^{133}Ba (Absorption Type F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.40		8.0E-11	4.2E-10	1.7E-09	2.6E-09
12 h	1.58		9.0E-11	4.8E-10	1.9E-09	2.9E-09
1 d	2.06		1.2E-10	6.2E-10	2.4E-09	3.8E-09
2 d	3.63		2.1E-10	1.1E-09	4.3E-09	6.7E-09
3 d	5.98		3.4E-10	1.8E-09	7.1E-09	1.1E-08
4 d	8.84		5.0E-10	2.7E-09	1.0E-08	1.6E-08
5 d	11.9		6.8E-10	3.6E-09	1.4E-08	2.2E-08
6 d	14.8		8.4E-10	4.5E-09	1.8E-08	2.7E-08
7 d	17.4		9.9E-10	5.3E-09	2.1E-08	3.2E-08
10 d	23.3		1.3E-09	7.0E-09	2.8E-08	4.3E-08
14 d	27.0		1.5E-09	8.2E-09	3.2E-08	5.0E-08
21 d	29.3		1.7E-09	8.9E-09	3.5E-08	5.4E-08
28 d	30.8		1.8E-09	9.3E-09	3.7E-08	5.7E-08

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 µm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon
(IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.8b. Doses from an intake by INGESTION of ^{133}Ba (f_1 = 0.1) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		2.0E-11	1.7E-10	2.7E-09	1.0E-09
12 h	1.08		2.1E-11	1.8E-10	2.9E-09	1.1E-09
1 d	1.38		2.7E-11	2.3E-10	3.7E-09	1.4E-09
2 d	2.85		5.5E-11	4.8E-10	7.6E-09	2.8E-09
3 d	6.25		1.2E-10	1.0E-09	1.7E-08	6.3E-09
4 d	12.9		2.5E-10	2.2E-09	3.5E-08	1.3E-08
5 d	23.3		4.5E-10	3.9E-09	6.2E-08	2.3E-08
6 d	35.8		7.0E-10	6.0E-09	9.6E-08	3.6E-08
7 d	47.7		9.3E-10	8.0E-09	1.3E-07	4.8E-08
10 d	70.9		1.4E-09	1.2E-08	1.9E-07	7.1E-08
14 d	83.4		1.6E-09	1.4E-08	2.2E-07	8.3E-08
21 d	90.9		1.8E-09	1.5E-08	2.4E-07	9.1E-08
28 d	95.4		1.9E-09	1.6E-08	2.6E-07	9.5E-08

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.9a. Doses from an intake by INHALATION of ^{137}Cs (Absorption Type F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		1.5E-09	1.5E-09	1.9E-09	9.2E-09
12 h	1.48		1.7E-09	1.7E-09	2.0E-09	1.0E-08
1 d	1.68		1.9E-09	1.9E-09	2.3E-09	1.1E-08
2 d	1.97		2.2E-09	2.2E-09	2.7E-09	1.3E-08
3 d	2.14		2.4E-09	2.4E-09	2.9E-09	1.4E-08
4 d	2.23		2.5E-09	2.5E-09	3.1E-09	1.5E-08
5 d	2.28		2.5E-09	2.6E-09	3.1E-09	1.5E-08
6 d	2.32		2.6E-09	2.6E-09	3.2E-09	1.6E-08
7 d	2.35		2.6E-09	2.6E-09	3.2E-09	1.6E-08
10 d	2.42		2.7E-09	2.7E-09	3.3E-09	1.6E-08
14 d	2.50		2.8E-09	2.8E-09	3.4E-09	1.7E-08
21 d	2.61		2.9E-09	2.9E-09	3.6E-09	1.8E-08
28 d	2.73		3.0E-09	3.1E-09	3.8E-09	1.8E-08

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.9b. Doses from an intake by INGESTION of ^{137}Cs (f_1 = 1) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			*Effective dose, Sv*
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.00		2.2E-09	2.3E-09	2.9E-09	1.4E-08
12 h	1.00		2.2E-09	2.3E-09	2.9E-09	1.4E-08
1 d	1.01		2.2E-09	2.3E-09	2.9E-09	1.4E-08
2 d	1.04		2.3E-09	2.4E-09	3.0E-09	1.4E-08
3 d	1.07		2.4E-09	2.5E-09	3.1E-09	1.4E-08
4 d	1.09		2.4E-09	2.5E-09	3.1E-09	1.5E-08
5 d	1.11		2.5E-09	2.5E-09	3.2E-09	1.5E-08
6 d	1.12		2.5E-09	2.6E-09	3.2E-09	1.5E-08
7 d	1.14		2.5E-09	2.6E-09	3.3E-09	1.5E-08
10 d	1.17		2.6E-09	2.7E-09	3.4E-09	1.6E-08
14 d	1.21		2.7E-09	2.8E-09	3.5E-09	1.6E-08
21 d	1.26		2.8E-09	2.9E-09	3.6E-09	1.7E-08
28 d	1.32		2.9E-09	3.0E-09	3.8E-09	1.8E-08

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.10a. Doses from an intake by INHALATION of ^{152}Eu (Absorption Type M) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		1.8E-08	6.9E-10	3.8E-09	4.2E-08
12 h	1.54		2.1E-08	7.7E-10	4.2E-09	4.7E-08
1 d	2.03		2.7E-08	1.0E-09	5.6E-09	6.2E-08
2 d	3.73		5.0E-08	1.9E-09	1.0E-08	1.2E-07
3 d	6.17		8.2E-08	3.1E-09	1.7E-08	1.9E-07
4 d	8.42		1.1E-07	4.2E-09	2.3E-08	2.6E-07
5 d	9.83		1.3E-07	5.0E-09	2.7E-08	3.0E-07
6 d	10.5		1.4E-07	5.3E-09	2.9E-08	3.2E-07
7 d	10.9		1.5E-07	5.5E-09	3.0E-08	3.4E-07
10 d	11.3		1.5E-07	5.7E-09	3.1E-08	3.5E-07
14 d	11.7		1.6E-07	5.9E-09	3.2E-08	3.6E-07
21 d	12.3		1.6E-07	6.2E-09	3.4E-08	3.8E-07
28 d	12.8		1.7E-07	6.4E-09	3.5E-08	3.9E-07

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.10b. Doses from an intake by INGESTION of ^{152}Eu (f_1 = 0.0005) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		2.5E-11	2.3E-10	6.7E-09	1.4E-09
12 h	1.08		2.6E-11	2.4E-10	7.1E-09	1.5E-09
1 d	1.39		3.4E-11	3.1E-10	9.2E-09	1.9E-09
2 d	3.04		7.4E-11	6.8E-10	2.0E-08	4.1E-09
3 d	7.58		1.8E-10	1.7E-09	5.0E-08	1.0E-08
4 d	19.8		4.8E-10	4.5E-09	1.3E-07	2.7E-08
5 d	52.2		1.3E-09	1.2E-08	3.4E-07	7.1E-08
6 d	136		3.3E-09	3.1E-08	9.0E-07	1.8E-07
7 d	336		8.1E-09	7.6E-08	2.2E-06	4.6E-07
10 d	1840		4.5E-08	4.1E-07	1.2E-05	2.5E-06
14 d	2420		5.9E-08	5.4E-07	1.6E-05	3.3E-06
21 d	2470		6.0E-08	5.6E-07	1.6E-05	3.4E-06
28 d	2490		6.0E-08	5.6E-07	1.6E-05	3.4E-06

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.11a. Doses from an intake by INHALATION of ^{154}Eu (Absorption Type M) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.37		3.9E-08	9.2E-10	6.5E-09	5.4E-08
12 h	1.54		4.4E-08	1.0E-09	7.3E-09	6.1E-08
1 d	2.03		5.8E-08	1.4E-09	9.6E-09	8.0E-08
2 d	3.74		1.1E-07	2.5E-09	1.8E-08	1.5E-07
3 d	6.18		1.8E-07	4.1E-09	2.9E-08	2.4E-07
4 d	8.42		2.4E-07	5.6E-09	4.0E-08	3.3E-07
5 d	9.84		2.8E-07	6.6E-09	4.7E-08	3.9E-07
6 d	10.6		3.0E-07	7.1E-09	5.0E-08	4.2E-07
7 d	10.9		3.1E-07	7.3E-09	5.2E-08	4.3E-07
10 d	11.3		3.2E-07	7.6E-09	5.4E-08	4.5E-07
14 d	11.7		3.3E-07	7.8E-09	5.6E-08	4.6E-07
21 d	12.3		3.5E-07	8.2E-09	5.8E-08	4.9E-07
28 d	12.8		3.6E-07	8.6E-09	6.1E-08	5.1E-07

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.11b. Doses from an intake by INGESTION of ^{154}Eu (f_1 = 0.0005) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		2.7E-11	2.4E-10	1.2E-08	2.1E-09
12 h	1.08		2.8E-11	2.6E-10	1.2E-08	2.2E-09
1 d	1.39		3.7E-11	3.4E-10	1.6E-08	2.8E-09
2 d	3.04		8.1E-11	7.4E-10	3.5E-08	6.2E-09
3 d	7.59		2.0E-10	1.8E-09	8.8E-08	1.5E-08
4 d	19.8		5.2E-10	4.8E-09	2.3E-07	4.0E-08
5 d	52.3		1.4E-09	1.3E-08	6.1E-07	1.1E-07
6 d	136		3.6E-09	3.3E-08	1.6E-06	2.8E-07
7 d	336		8.9E-09	8.1E-08	3.9E-06	6.8E-07
10 d	1840		4.9E-08	4.5E-07	2.1E-05	3.7E-06
14 d	2420		6.4E-08	5.9E-07	2.8E-05	4.9E-06
21 d	2470		6.5E-08	6.0E-07	2.9E-05	5.0E-06
28 d	2500		6.6E-08	6.0E-07	2.9E-05	5.1E-06

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.12a. Doses from an intake by INHALATION of ^{192}Ir (Absorption Type F) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.39		7.8E-10	7.4E-10	3.6E-09	3.1E-09
12 h	1.56		8.7E-10	8.4E-10	4.0E-09	3.5E-09
1 d	1.97		1.1E-09	1.1E-09	5.1E-09	4.4E-09
2 d	2.93		1.6E-09	1.6E-09	7.6E-09	6.5E-09
3 d	3.78		2.1E-09	2.0E-09	9.8E-09	8.4E-09
4 d	4.33		2.4E-09	2.3E-09	1.1E-08	9.6E-09
5 d	4.65		2.6E-09	2.5E-09	1.2E-08	1.0E-08
6 d	4.85		2.7E-09	2.6E-09	1.3E-08	1.1E-08
7 d	5.01		2.8E-09	2.7E-09	1.3E-08	1.1E-08
10 d	5.38		3.0E-09	2.9E-09	1.4E-08	1.2E-08
14 d	5.85		3.3E-09	3.1E-09	1.5E-08	1.3E-08
21 d	6.63		3.7E-09	3.5E-09	1.7E-08	1.5E-08
28 d	7.40		4.1E-09	4.0E-09	1.9E-08	1.6E-08

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: F
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.12b. Doses from an intake by INHALATION of ^{192}Ir (Absorption Type M) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	13.2		2.5E-07	3.1E-09	4.6E-08	6.0E-08
12 h	13.8		2.7E-07	3.3E-09	4.8E-08	6.3E-08
1 d	14.5		2.8E-07	3.5E-09	5.0E-08	6.6E-08
2 d	15.1		2.9E-07	3.6E-09	5.2E-08	6.8E-08
3 d	15.5		3.0E-07	3.7E-09	5.4E-08	7.0E-08
4 d	15.9		3.1E-07	3.8E-09	5.5E-08	7.2E-08
5 d	16.2		3.1E-07	3.9E-09	5.6E-08	7.4E-08
6 d	16.6		3.2E-07	4.0E-09	5.8E-08	7.6E-08
7 d	17.0		3.3E-07	4.1E-09	5.9E-08	7.7E-08
10 d	18.3		3.5E-07	4.4E-09	6.3E-08	8.3E-08
14 d	20.1		3.9E-07	4.8E-09	6.9E-08	9.1E-08
21 d	23.5		4.5E-07	5.6E-09	8.1E-08	1.1E-07
28 d	27.3		5.3E-07	6.5E-09	9.5E-08	1.2E-07

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.12c. Doses from an intake by INHALATION of ^{192}Ir (Absorption Type S) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	11.9		2.7E-07	2.4E-09	4.2E-08	6.6E-08
12 h	12.4		2.8E-07	2.6E-09	4.4E-08	6.9E-08
1 d	13.0		2.9E-07	2.7E-09	4.6E-08	7.2E-08
2 d	13.4		3.0E-07	2.8E-09	4.8E-08	7.4E-08
3 d	13.7		3.1E-07	2.8E-09	4.9E-08	7.6E-08
4 d	14.0		3.2E-07	2.9E-09	5.0E-08	7.7E-08
5 d	14.3		3.2E-07	2.9E-09	5.1E-08	7.9E-08
6 d	14.6		3.3E-07	3.0E-09	5.2E-08	8.1E-08
7 d	14.8		3.4E-07	3.0E-09	5.3E-08	8.2E-08
10 d	15.7		3.6E-07	3.2E-09	5.6E-08	8.7E-08
14 d	16.9		3.8E-07	3.5E-09	6.0E-08	9.3E-08
21 d	19.1		4.3E-07	3.9E-09	6.8E-08	1.1E-07
28 d	21.5		4.9E-07	4.4E-09	7.6E-08	1.2E-07

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: S
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.12d. Doses from an intake by INGESTION of ^{192}Ir (f_1 = 0.01) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		3.2E-11	1.9E-10	8.5E-09	1.4E-09
12 h	1.08		3.4E-11	2.0E-10	9.1E-09	1.5E-09
1 d	1.40		4.5E-11	2.6E-10	1.2E-08	1.9E-09
2 d	3.06		9.8E-11	5.7E-10	2.6E-08	4.2E-09
3 d	7.46		2.4E-10	1.4E-09	6.3E-08	1.0E-08
4 d	18.1		5.8E-10	3.4E-09	1.5E-07	2.5E-08
5 d	40.2		1.3E-09	7.5E-09	3.4E-07	5.5E-08
6 d	74.2		2.4E-09	1.4E-08	6.2E-07	1.0E-07
7 d	109		3.5E-09	2.0E-08	9.2E-07	1.5E-07
10 d	155		4.9E-09	2.9E-08	1.3E-06	2.1E-07
14 d	171		5.5E-09	3.2E-08	1.4E-06	2.3E-07
21 d	194		6.2E-09	3.6E-08	1.6E-06	2.6E-07
28 d	217		6.9E-09	4.1E-08	1.8E-06	2.9E-07

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.13a. Doses from an intake by INHALATION of ^{210}Po (Absorption Type M) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	6720		3.0E-02	1.1E-04	5.4E-11	1.7E-02
2 d	3410		1.5E-02	5.6E-05	2.8E-11	8.6E-03
3 d	3310		1.5E-02	5.5E-05	2.7E-11	8.4E-03
4 d	3340		1.5E-02	5.5E-05	2.7E-11	8.4E-03
5 d	3380		1.5E-02	5.6E-05	2.7E-11	8.6E-03
6 d	3430		1.5E-02	5.7E-05	2.8E-11	8.7E-03
7 d	3470		1.6E-02	5.7E-05	2.8E-11	8.8E-03
10 d	3610		1.6E-02	6.0E-05	2.9E-11	9.1E-03
14 d	3810		1.7E-02	6.3E-05	3.1E-11	9.6E-03
21 d	4180		1.9E-02	6.9E-05	3.4E-11	1.1E-02
28 d	4600		2.1E-02	7.6E-05	3.7E-11	1.2E-02

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.13b. Doses from an intake by INGESTION of ^{210}Po (f_1 = 0.1) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	5190		4.4E-05	1.2E-04	9.5E-11	1.3E-03
2 d	2340		2.0E-05	5.3E-05	4.3E-11	5.7E-04
3 d	2260		1.9E-05	5.1E-05	4.2E-11	5.5E-04
4 d	2300		1.9E-05	5.2E-05	4.2E-11	5.6E-04
5 d	2340		2.0E-05	5.3E-05	4.3E-11	5.7E-04
6 d	2390		2.0E-05	5.4E-05	4.4E-11	5.8E-04
7 d	2430		2.1E-05	5.5E-05	4.5E-11	6.0E-04
10 d	2570		2.2E-05	5.8E-05	4.7E-11	6.3E-04
14 d	2770		2.4E-05	6.2E-05	5.1E-11	6.8E-04
21 d	3170		2.7E-05	7.1E-05	5.8E-11	7.8E-04
28 d	3610		3.1E-05	8.1E-05	6.6E-11	8.9E-04

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.14a. Doses from an intake by INHALATION of ^{226}Ra (ABSORPTION TYPE M) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	13.1		5.1E-05	6.5E-08	5.2E-08	3.4E-05
12 h	13.8		5.3E-05	6.8E-08	5.5E-08	3.5E-05
1 d	14.3		5.5E-05	7.1E-08	5.7E-08	3.7E-05
2 d	14.8		5.7E-05	7.3E-08	5.9E-08	3.8E-05
3 d	15.0		5.8E-05	7.4E-08	6.0E-08	3.9E-05
4 d	15.3		5.9E-05	7.5E-08	6.1E-08	3.9E-05
5 d	15.5		6.0E-05	7.7E-08	6.2E-08	4.0E-05
6 d	15.7		6.1E-05	7.8E-08	6.2E-08	4.0E-05
7 d	16.0		6.2E-05	7.9E-08	6.3E-08	4.1E-05
10 d	16.7		6.4E-05	8.2E-08	6.6E-08	4.3E-05
14 d	17.6		6.8E-05	8.7E-08	7.0E-08	4.5E-05
21 d	19.3		7.4E-05	9.5E-08	7.7E-08	4.9E-05
28 d	21.0		8.1E-05	1.0E-07	8.3E-08	5.4E-05

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.14b. Doses from an intake by INGESTION of ^{226}Ra (f_1 = 0.2) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		1.0E-09	8.7E-09	8.1E-09	2.8E-07
12 h	1.08		1.1E-09	9.3E-09	8.6E-09	3.0E-07
1 d	1.36		1.4E-09	1.2E-08	1.1E-08	3.7E-07
2 d	2.64		2.6E-09	2.3E-08	2.1E-08	7.3E-07
3 d	5.21		5.2E-09	4.5E-08	4.1E-08	1.4E-06
4 d	9.30		9.3E-09	8.0E-08	7.4E-08	2.6E-06
5 d	14.4		1.4E-08	1.2E-07	1.1E-07	4.0E-06
6 d	19.7		2.0E-08	1.7E-07	1.6E-07	5.4E-06
7 d	24.3		2.4E-08	2.1E-07	1.9E-07	6.7E-06
10 d	34.0		3.4E-08	2.9E-07	2.7E-07	9.3E-06
14 d	40.3		4.0E-08	3.5E-07	3.2E-07	1.1E-05
21 d	45.6		4.6E-08	3.9E-07	3.6E-07	1.3E-05
28 d	49.7		5.0E-08	4.3E-07	3.9E-07	1.4E-05

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.14c. Doses from an intake by INHALATION of ^{226}Ra (Absorption Type M) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	639		2.5E-03	3.2E-06	2.5E-06	1.6E-03
2 d	3,220		1.2E-02	1.6E-05	1.3E-05	8.2E-03
3 d	4,860		1.9E-02	2.4E-05	1.9E-05	1.2E-02
4 d	6,830		2.6E-02	3.4E-05	2.7E-05	1.7E-02
5 d	9,460		3.7E-02	4.7E-05	3.8E-05	2.4E-02
6 d	12,900		5.0E-02	6.4E-05	5.1E-05	3.3E-02
7 d	17,200		6.6E-02	8.5E-05	6.8E-05	4.4E-02
10 d	34,900		1.3E-01	1.7E-04	1.4E-04	8.9E-02
14 d	59,400		2.3E-01	2.9E-04	2.4E-04	1.5E-01
21 d	80,100		3.1E-01	4.0E-04	3.2E-04	2.1E-01
28 d	90,500		3.5E-01	4.5E-04	3.6E-04	2.3E-01

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.14d. Doses from an intake by INGESTION of ^{226}Ra (f_1 = 0.2) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	342		3.4E-07	2.9E-06	2.7E-06	9.4E-05
2 d	1,750		1.8E-06	1.5E-05	1.4E-05	4.8E-04
3 d	2,680		2.7E-06	2.3E-05	2.1E-05	7.4E-04
4 d	3,840		3.8E-06	3.3E-05	3.1E-05	1.1E-03
5 d	5,480		5.5E-06	4.7E-05	4.4E-05	1.5E-03
6 d	7,770		7.8E-06	6.7E-05	6.2E-05	2.1E-03
7 d	10,900		1.1E-05	9.4E-05	8.7E-05	3.0E-03
10 d	28,100		2.8E-05	2.4E-04	2.2E-04	7.7E-03
14 d	71,100		7.1E-05	6.1E-04	5.7E-04	2.0E-02
21 d	134,000		1.3E-04	1.2E-03	1.1E-03	3.7E-02
28 d	160,000		1.6E-04	1.4E-03	1.3E-03	4.4E-02

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.15a. Doses from an intake by INHALATION of ^{238}Pu (ABSORPTION TYPE S) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	11.8		7.2E-05	2.0E-09	1.8E-09	1.2E-04
12 h	12.4		7.6E-05	2.1E-09	1.9E-09	1.3E-04
1 d	12.8		7.9E-05	2.2E-09	1.9E-09	1.3E-04
2 d	13.2		8.1E-05	2.2E-09	2.0E-09	1.4E-04
3 d	13.4		8.2E-05	2.3E-09	2.0E-09	1.4E-04
4 d	13.5		8.2E-05	2.3E-09	2.0E-09	1.4E-04
5 d	13.6		8.3E-05	2.3E-09	2.1E-09	1.4E-04
6 d	13.8		8.4E-05	2.3E-09	2.1E-09	1.4E-04
7 d	13.9		8.5E-05	2.4E-09	2.1E-09	1.4E-04
10 d	14.3		8.7E-05	2.4E-09	2.2E-09	1.5E-04
14 d	14.8		9.0E-05	2.5E-09	2.2E-09	1.5E-04
21 d	15.7		9.6E-05	2.7E-09	2.4E-09	1.6E-04
28 d	16.5		1.0E-04	2.8E-09	2.5E-09	1.7E-04

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: S
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.15b. Doses from an intake by INGESTION of ^{238}Pu (f_1 = 1E-05) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		5.4E-13	4.4E-12	3.6E-10	9.0E-09
12 h	1.08		5.8E-13	4.7E-12	3.9E-10	9.6E-09
1 d	1.39		7.5E-13	6.0E-12	5.0E-10	1.2E-08
2 d	3.04		1.6E-12	1.3E-11	1.1E-09	2.7E-08
3 d	7.60		4.1E-12	3.3E-11	2.7E-09	6.8E-08
4 d	19.9		1.1E-11	8.6E-11	7.1E-09	1.8E-07
5 d	53.3		2.9E-11	2.3E-10	1.9E-08	4.7E-07
6 d	144		7.7E-11	6.2E-10	5.2E-08	1.3E-06
7 d	389		2.1E-10	1.7E-09	1.4E-07	3.5E-06
10 d	7,280		3.9E-09	3.1E-08	2.6E-06	6.5E-05
14 d	84,000		4.5E-08	3.6E-07	3.0E-05	7.5E-04
21 d	104,700		5.6E-08	4.5E-07	3.8E-05	9.3E-04
28 d	105,000		5.6E-08	4.5E-07	3.8E-05	9.3E-04

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.15c. Doses from an intake by INHALATION of ^{238}Pu (ABSORPTION TYPE S) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	411,000		2.5E+00	7.0E-05	6.2E-05	4.2E+00
2 d	706,000		4.3E+00	1.2E-04	1.1E-04	7.3E+00
3 d	1,140,000		7.0E+00	1.9E-04	1.7E-04	1.2E+01
4 d	1,590,000		9.7E+00	2.7E-04	2.4E-04	1.6E+01
5 d	2,040,000		1.2E+01	3.5E-04	3.1E-04	2.1E+01
6 d	2,490,000		1.5E+01	4.2E-04	3.8E-04	2.6E+01
7 d	2,910,000		1.8E+01	4.9E-04	4.4E-04	3.0E+01
10 d	3,930,000		2.4E+01	6.7E-04	6.0E-04	4.0E+01
14 d	4,590,000		2.8E+01	7.8E-04	7.0E-04	4.7E+01
21 d	4,890,000		3.0E+01	8.3E-04	7.4E-04	5.0E+01
28 d	4,970,000		3.0E+01	8.4E-04	7.5E-04	5.1E+01

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: S
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.15d. Doses from an intake by INGESTION of ^{238}Pu (f_1 = 1E-05) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	14,900,000		8.0E-06	6.4E-05	5.3E-03	1.3E-01
2 d	19,300,000		1.0E-05	8.4E-05	6.9E-03	1.7E-01
3 d	34,600,000		1.9E-05	1.5E-04	1.2E-02	3.1E-01
4 d	53,900,000		2.9E-05	2.3E-04	1.9E-02	4.8E-01
5 d	77,300,000		4.1E-05	3.3E-04	2.8E-02	6.9E-01
6 d	106,000,000		5.7E-05	4.6E-04	3.8E-02	9.4E-01
7 d	140,000,000		7.5E-05	6.1E-04	5.0E-02	1.2E+00
10 d	274,000,000		1.5E-04	1.2E-03	9.8E-02	2.4E+00
14 d	450,000,000		2.4E-04	1.9E-03	1.6E-01	4.0E+00
21 d	582,000,000		3.1E-04	2.5E-03	2.1E-01	5.2E+00
28 d	632,000,000		3.4E-04	2.7E-03	2.3E-01	5.6E+00

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.16a. Doses from an intake by INHALATION of ^{241}Am (ABSORPTION TYPE M) corresponding to a measurement of 1 Bq in LUNGS at specified times after a single intake.

Measured quantity: Lungs	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	13.1		6.8E-05	1.0E-07	9.7E-09	4.0E-04
12 h	13.8		7.1E-05	1.1E-07	1.0E-08	4.2E-04
1 d	14.3		7.4E-05	1.1E-07	1.1E-08	4.4E-04
2 d	14.8		7.6E-05	1.2E-07	1.1E-08	4.6E-04
3 d	15.0		7.8E-05	1.2E-07	1.1E-08	4.6E-04
4 d	15.3		7.9E-05	1.2E-07	1.1E-08	4.7E-04
5 d	15.5		8.0E-05	1.2E-07	1.1E-08	4.8E-04
6 d	15.7		8.1E-05	1.2E-07	1.2E-08	4.8E-04
7 d	16.0		8.2E-05	1.3E-07	1.2E-08	4.9E-04
10 d	16.7		8.6E-05	1.3E-07	1.2E-08	5.1E-04
14 d	17.6		9.1E-05	1.4E-07	1.3E-08	5.4E-04
21 d	19.3		1.0E-04	1.5E-07	1.4E-08	5.9E-04
28 d	21.0		1.1E-04	1.7E-07	1.5E-08	6.5E-04

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.16b. Doses from an intake by INGESTION of ^{241}Am (f_1 = 0.0005) corresponding to a measurement of 1 Bq in WHOLE BODY at specified times after a single intake.

Measured quantity: Whole body	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
6 h	1.01		1.3E-11	1.2E-10	1.9E-09	2.1E-07
12 h	1.08		1.4E-11	1.3E-10	2.0E-09	2.2E-07
1 d	1.39		1.8E-11	1.7E-10	2.6E-09	2.8E-07
2 d	3.04		3.9E-11	3.7E-10	5.6E-09	6.2E-07
3 d	7.58		9.7E-11	9.2E-10	1.4E-08	1.5E-06
4 d	19.8		2.5E-10	2.4E-09	3.6E-08	4.0E-06
5 d	52.1		6.6E-10	6.3E-09	9.6E-08	1.1E-05
6 d	135		1.7E-09	1.6E-08	2.5E-07	2.8E-05
7 d	332		4.2E-09	4.0E-08	6.1E-07	6.8E-05
10 d	1730		2.2E-08	2.1E-07	3.2E-06	3.5E-04
14 d	2220		2.8E-08	2.7E-07	4.1E-06	4.5E-04
21 d	2237		2.8E-08	2.7E-07	4.1E-06	4.6E-04
28 d	2240		2.9E-08	2.7E-07	4.1E-06	4.6E-04

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.16c. Doses from an intake by INHALATION of ^{241}Am (ABSORPTION TYPE M) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	544		2.8E-03	4.3E-06	4.0E-07	1.7E-02
2 d	4,110		2.1E-02	3.2E-05	3.0E-06	1.3E-01
3 d	7,200		3.7E-02	5.7E-05	5.3E-06	2.2E-01
4 d	10,400		5.4E-02	8.2E-05	7.6E-06	3.2E-01
5 d	12,800		6.6E-02	1.0E-04	9.5E-06	4.0E-01
6 d	14,500		7.5E-02	1.1E-04	1.1E-05	4.5E-01
7 d	15,800		8.2E-02	1.2E-04	1.2E-05	4.9E-01
10 d	18,500		9.6E-02	1.5E-04	1.4E-05	5.7E-01
14 d	21,800		1.1E-01	1.7E-04	1.6E-05	6.7E-01
21 d	27,100		1.4E-01	2.1E-04	2.0E-05	8.4E-01
28 d	31,700		1.6E-01	2.5E-04	2.3E-05	9.8E-01

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.16d. Doses from an intake by INGESTION of ^{241}Am (f_1 = 0.0005) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	33,700		4.3E-07	4.1E-06	6.2E-05	6.9E-03
2 d	218,000		2.8E-06	2.6E-05	4.0E-04	4.5E-02
3 d	451,000		5.8E-06	5.5E-05	8.3E-04	9.2E-02
4 d	754,000		9.6E-06	9.1E-05	1.4E-03	1.5E-01
5 d	1,060,000		1.4E-05	1.3E-04	1.9E-03	2.2E-01
6 d	1,310,000		1.7E-05	1.6E-04	2.4E-03	2.7E-01
7 d	1,520,000		1.9E-05	1.8E-04	2.8E-03	3.1E-01
10 d	2,040,000		2.6E-05	2.5E-04	3.7E-03	4.2E-01
14 d	2,820,000		3.6E-05	3.4E-04	5.2E-03	5.7E-01
21 d	4,640,000		5.9E-05	5.6E-04	8.5E-03	9.5E-01
28 d	6,910,000		8.8E-05	8.4E-04	1.3E-02	1.4E+00

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.17a. Doses from an intake by INHALATION of ^{252}Cf (ABSORPTION TYPE M) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	742		5.9E-03	2.8E-05	7.1E-06	1.1E-02
2 d	7,600		6.1E-02	2.9E-04	7.3E-05	1.1E-01
3 d	40,500		3.2E-01	1.5E-03	3.9E-04	6.0E-01
4 d	56,400		4.5E-01	2.1E-03	5.4E-04	8.4E-01
5 d	58,700		4.7E-01	2.2E-03	5.6E-04	8.7E-01
6 d	59,600		4.8E-01	2.3E-03	5.7E-04	8.8E-01
7 d	60,500		4.8E-01	2.3E-03	5.8E-04	8.9E-01
10 d	63,000		5.0E-01	2.4E-03	6.1E-04	9.3E-01
14 d	66,500		5.3E-01	2.5E-03	6.4E-04	9.8E-01
21 d	72,700		5.8E-01	2.7E-03	7.0E-04	1.1E+00
28 d	79,000		6.3E-01	3.0E-03	7.6E-04	1.2E+00

Notes:
Doses calculated for adults
Route of intake: Acute inhalation
Activity median aerodynamic diameter (AMAD) = 5 μm
Absorption Type: M
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Table A13.17b. Doses from an intake by INGESTION of ^{252}Cf (f_1 = 0.0005) corresponding to a measurement of 1 Bq/day in URINE at specified times after a single intake.

Measured quantity: Urine	Intake, Bq		RBE-weighted absorbed dose, Gy-Eq			Effective dose, Sv
		Organ:	Lungs	Red bone marrow	Colon	-
		Integration period:	30 d			To age 70 y
Measurement time						
1 d	48,200		5.8E-06	8.6E-05	1.1E-03	4.4E-03
2 d	260,000		3.1E-05	4.6E-04	5.9E-03	2.4E-02
3 d	3,840,000		4.7E-04	6.8E-03	8.7E-02	3.5E-01
4 d	36,300,000		4.4E-03	6.4E-02	8.2E-01	3.3E+00
5 d	76,800,000		9.3E-03	1.4E-01	1.7E+00	6.9E+00
6 d	82,600,000		1.0E-02	1.5E-01	1.9E+00	7.5E+00
7 d	83,000,000		1.0E-02	1.5E-01	1.9E+00	7.5E+00
10 d	83,300,000		1.0E-02	1.5E-01	1.9E+00	7.5E+00
14 d	83,500,000		1.0E-02	1.5E-01	1.9E+00	7.6E+00
21 d	84,000,000		1.0E-02	1.5E-01	1.9E+00	7.6E+00
28 d	84,400,000		1.0E-02	1.5E-01	1.9E+00	7.6E+00

Notes:
Doses calculated for adults
Route of intake: Acute ingestion
Organs for which absorbed doses are calculated: Lungs, Red bone marrow or Colon (IAEA EPR-Medical, 2005)
The RBE-weighted absorbed dose is obtained by multiplying the absorbed dose by the RBE factor [Table H5]. The units are Gray-Equivalent (Gy-Eq)
Integration period for absorbed dose = 30 d

Annex 14: Methodology applied by WHO for developing guidance on health interventions for Chapters J and K of this Handbook

How the TMT project started

In response to the EC Euratom's Sixth Framework Programme call for proposals, five organisations in the EU and one organisation in an Associated Country with relevant expertise in the field of preparedness and response to radiation emergencies formed a consortium[1] and invited WHO to take part in this project. A proposal for a joint project called "Triage, Monitoring and Treatment - handbook for management of the public in the event of malevolent use of radiation" (TMT Handbook) was submitted and awarded funding. The project started in September 2006 with the aim of producing a practicable tool for the effective and timely management of people following an incident involving malevolent use of radiation, building on earlier developments in national and regional European programmes.

How the expert panel on health interventions was identified

The handbook was drafted by the scientific staff of the consortium organisations, according to their areas of specialisation and expertise. WHO took the lead for the development of guidance on health interventions (Chapters J and K of this Handbook: Work Package 4). To address this task WHO convened an expert panel which brought together acknowledged professionals from its Radiation Emergency Medical Preparedness and Assistance network (REMPAN). The selection of these experts was based on their specialisation field, expertise, and experience in the field of medical and public health response in radiation emergencies. The selection ensured participation of experts who were directly involved in the diagnosis and treatment of people accidentally exposed to radiation as well as in the management of public health response during past radiation emergencies. Conflict of interest statements with accompanying explanatory notes were sent to all the invited experts. No conflicts of interest have been declared by any of them.

1 Belgian Nuclear Research Centre (SCK•CEN), Belgium; Norwegian Radiation Protection Authority (NRPA), Norway; Health Protection Agency (HPA), United Kingdom; Radiation and Nuclear Safety Authority (STUK), Finland; Enviros Consulting, United Kingdom; and Central Laboratory for Radiation Protection (CLOR), Poland.

How the best approach was identified

This Handbook is based on a harmonisation and development of current approaches across the European Union and is consistent with current international guidance. Recommended health interventions are evidence-based statements to assist decision-making. In areas where clinical evidence was limited, recommendations were based on best available practice, the experts' opinion, and lessons identified in recent radiation accidents.

A comprehensive literature search was conducted using PubMed and library databases of the consortium organisations, as well as other international, regional and national databases, with contributions from the REMPAN experts. Particular efforts were made to identify systematic literature reviews and evidence related to health effects of ionising radiation, diagnosis and treatment of radiation injuries, long-term health surveillance, prevention and management of psychological impact. A survey of current practice in European countries was also conducted as a part of the project (Work Package 2).

How the expert panel worked

The first consultation was held in August 2007 in WHO Headquarters (Geneva, Switzerland) with a dual purpose: (i) to review and evaluate available evidence on medical and public health preparedness and response to radiation emergencies resulting from malevolent acts; and (ii) to develop as far as possible an outline of particular chapters (J and K) of the TMT Handbook.

The consultation was attended by the following REMPAN experts: M. Akashi (NIRS, Japan); R. N. Gent (HPA, UK); P. Gourmelon (IRSN, France); S. Joussineau (Karolinska University Hospital, Sweden); V. List (Karlsruhe Res. Centre, Germany); D. Lloyd (HPA,UK); N. Valverde (Rio University, Brazil), and A. L. Wiley (REAC/TS, USA). The TMT project Secretariat was represented by C. R. Palma (TMT Project Co-ordinator, SCK-CEN, Belgium) and P. Kruse (TMT Technical Secretariat, Enviros, UK). The WHO Secretariat was represented by Z. Carr and M. R. Pérez (WHO/PHE).

The output of the consultation was a report that constituted the basis for the development of the draft chapters, including:

- A summary of the discussions conducted during working sessions on diagnosis, treatment and follow-up of casualties as well as public health response to radiation emergencies resulting from malevolent acts;
- Identified areas where evidence-based consensus existed and more controversial areas requiring further evidence retrieval;
- Generic recommendations on health interventions in radiation emergencies resulting from malevolent acts;
- General recommendations on the outline of the respective chapter of the TMT Handbook;
- List of relevant terms requiring harmonisation and core definitions to be included in a glossary; and
- List of relevant publications to be referenced and used for the Handbook development, and recommendations to expand literature research.

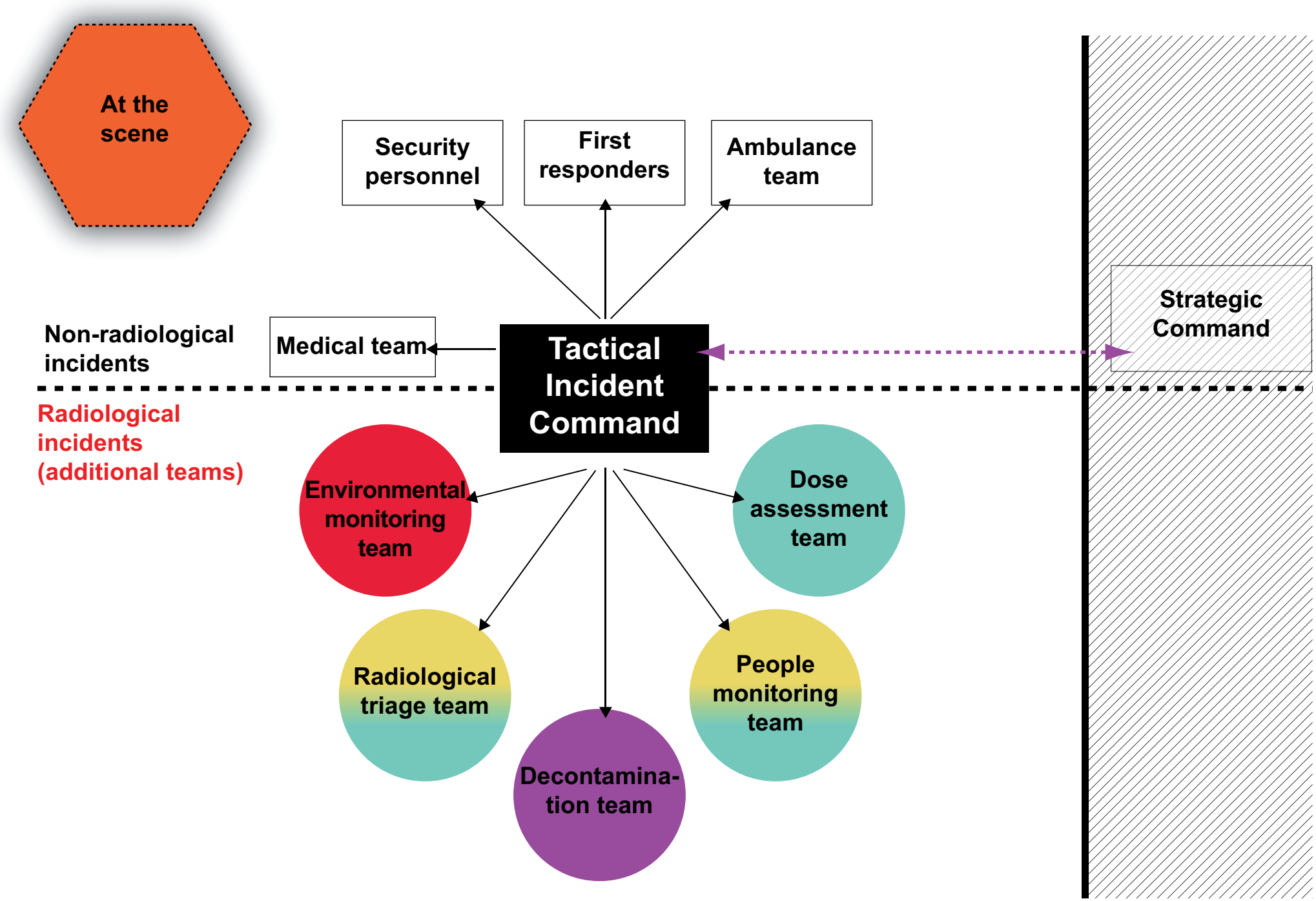
The expert panel identified some overlapping issues bridging pre-hospital and hospital responses and recommended further interaction between the consortium members involved in Work Packages (WP) 3 and 4 addressing respective issues. A joint meeting of the WP3 and 4 contributors was held in November 2007 in Brussels, Belgium to ensure harmonisation and consistency between the different chapters. This joint meeting was attended by the following aforementioned experts: R. N. Gent, S. Joussineau, V. List and D. Lloyd. The TMT project Secretariat was represented by C. Rojas-Palma (TMT Project Co-ordinator, SCK-CEN, Belgium) and K. Smith (TMT Technical Secretariat, Enviros, UK). The following TMT consortium members involved in WP3 attended: G. Etherington (HPA, UK), A. Hodgson (HPA, UK), W. Paile (STUK, Finland), T. Rahola (STUK, Finland). M. R. Pérez (PHE, WHO) attended the meeting representing the consortium members involved in the development of WP4. The European Commission was represented by M. Hugon.

Based on the evidence acquired from the literature search and the recommendations provided by the expert panel during the two meetings mentioned above, a draft module including information on hospital

response and public health actions was prepared in December 2007. Following internal review and revision, this draft was circulated for comments among the expert panel members. The first draft of the Handbook was finalised in March 2008. In addition to its circulation for review experts, the draft was distributed to a wide range of end-users and stake-holders, who evaluated the Handbook and/or tested it in suitable national emergency response exercises.

The feedback on the draft Handbook and experience from its use in national exercises were collected during the TMT Feedback Workshop held in December 2008 (Lillehammer, Norway), with the participation of end-users, technical experts, TMT consortium members and EC representatives. A Technical Meeting of the consortium members was convened at the end of the Workshop to address specifically the comments received during the feedback workshop. A final peer review was conducted with the contribution of REMPAN experts.

It is anticipated that the recommendations on health interventions provided in chapters J and K of this Handbook will remain valid at least until 2014. The Department of Public Health and Environment at WHO Headquarters in Geneva (WHO/PHE) is responsible for reviewing recommendations on health interventions. WHO/PHE can, if deemed necessary, publish new or revised recommendations based on emerging scientific evidence, at any time.


At the scene
Security personnel
First responders
Ambulance team
Strategic Command
Non-radiological incidents
Medical team
Tactical Incident Command
Radiological incidents (additional teams)
Environmental monitoring team
Dose assessment team
Radiological triage team
People monitoring team
Decontamina-tion team

Consortium members:

TMT Handbook

Belgian Nuclear Research Centre, Belgium

Norwegian Radiation Protection Authority, Norway

Health Protection Agency, United Kingdom

World Health Organization

Radiation and Nuclear Safety Authority, Finland

Enviros Consulting Ltd., United Kingdom

Central Laboratory for Radiological Protection, Poland

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