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EMERGENCY PREPAREDNESS
AND RESPONSE

Generic procedures for medical response during a nuclear or radiological emergency

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Co-sponsored by IAEA and WHO

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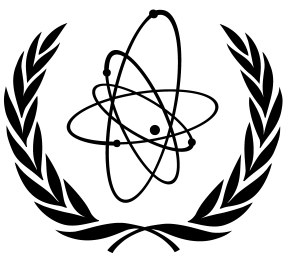

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FOREWORD

The aim of this publication is to serve as a practical resource for planning the medical response to a nuclear or radiological emergency. It fulfils in part functions assigned to the IAEA under Article 5.a(ii) of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Assistance Convention), namely, to collect and disseminate to States Parties and Member States information concerning methodologies, techniques and available results of research relating to such emergencies.

Effective medical response is a necessary component of the overall response to nuclear or radiological (radiation) emergencies. In general, the medical response may represent a difficult challenge for the authorities due to the complexity of the situation, often requiring specialized expertise, and special organizational arrangements and materials. To be effective, adequate planning and preparedness are needed.

In March 2002, the IAEA's Board of Governors approved a Safety Requirements publication Preparedness and Response for a Nuclear or Radiological Emergency, jointly sponsored by seven international organizations, including the World Health Organization (WHO), which establishes the requirements for an adequate level of preparedness and response for a nuclear or radiological emergency in any State. The Safety Requirements state, inter alia, that "…arrangements shall be made for medical personnel…to be made aware of the medical symptoms of radiation exposure and of the appropriate notification procedures and other immediate actions warranted if a nuclear or radiological emergency is suspected." [para 4.77]. In 2004, the IAEA General Conference, in resolution GC(48)/RES/10, encouraged Member States to "implement the Safety Requirements for Preparedness and Response to a Nuclear or Radiological Emergency".

The 2003 General Conference in resolution GC(47)/RES/7 encouraged Member States to "adopt IAEA standards, procedures and systems developed as part of international cooperation" and to "…contribute to the international efforts to develop a consistent, coherent and sustainable joint programme for improved and more efficient international response to nuclear and radiological emergencies…". This manual, if implemented, should help to contribute to coherent international response.

The manual provides the practical tools and generic procedures for use by emergency medical personnel during an emergency situation. It also provides guidance to be used at the stage of preparedness for development of medical response capabilities. The manual also addresses mass casualty emergencies resulting from malicious acts involving radioactive material. This part was supported by the Nuclear Security Fund. The manual was developed based on a number of assumptions about national and local capabilities. Therefore, it must be reviewed and revised as part of the planning process to match the potential accidents, threats, local conditions and other unique characteristics of the facility where it may be used.

The IAEA wishes to acknowledge the contribution of the WHO, which is co-sponsoring this publication. The IAEA officer responsible for this publication was E. Buglova of the Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety and Security.

EDITORIAL NOTE

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

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1. INTRODUCTION

1.1. BACKGROUND

Radiation emergencies may involve facility, hospital and other personnel, emergency workers, medical patients, and members of the general public. Nuclear emergencies, with Chernobyl as a dramatic example, may result in significant public overexposure. Over the past two decades a number of members of the public have received high doses as a result of lost or stolen sources used either in industrial radiography or medical therapy. Examples of recent serious exposures of the public are emergencies in Brazil (1987), Georgia (1997), Peru (1999), and Thailand (2000). Emergency exposures at high dose rates may also involve workers (e.g. emergencies in San Salvador, El Salvador in 1989, in Soreq, Israel in 1990, in Nesvizh, Belarus in 1991) Emergencies in Costa Rica (1996), Panama (2000) and Poland (2001) have shown that medical patients may receive significant overexposures for different reasons (e.g. errors in calibration, equipment failure, or miscalculation in administered doses of radionuclides).

Moreover, the general public and also emergency workers could be exposed to radiation or be contaminated as a consequence of malicious acts involving radioactive material. This represents a new challenge for emergency responders in some aspects of response. Without adequate preparedness of the medical community for such radiation emergencies, medical management of the situation could be ineffective.

Experience has shown that in many radiation emergencies, the severity and extent of the medical consequences could be restricted by effective general and, in particular, medical response. Therefore, the preparedness for medical response to radiation emergencies should be in place in all countries.

This manual, published as part of the IAEA Emergency Preparedness and Response Series, is consistent with Safety Requirements publication Preparedness and Response for a Nuclear or Radiological Emergency [1].

It builds on the IAEA Safety Report on Planning the Medical Response to Radiological Accidents (IAEA–WHO, Safety Reports Series No. 4).

The procedures of this manual could be used at the preparedness stage to train medical personnel participating in response to radiation emrgencies.

The procedures and data in this publication have been prepared with due attention to accuracy. However, comments are welcome and, following a period that will allow for a more extensive review, the IAEA will revise the manual as part of the process of continual improvement. In the meantime, it remains the responsibility of the users to ensure that the information is correct and appropriate to their purposes.

The practical guidance is provided in the form of generic procedures. In order to be effective, these procedures are to be adapted as part of the preparedness process to be integrated into the national and local systems and infrastructure in the country where they are used, and only personnel who have been trained and drilled are to use them. Furthermore, the application of each procedure will depend on the details of each emergency. Although the steps in the procedures are listed in a general sequence of

performance, it is possible that the sequence may need to be adapted at the time of the response.

Therefore, careful review and adaptation of its contents are strongly recommended prior to using this manual. As part of the planning process, it is advisable that this manual be reviewed and amended to take into account current radiation sources and radiological practices, lessons identified from radiation emergencies, changing local conditions, national criteria and other characteristics of the area or facility where it may be used.

1.2. OBJECTIVES

The aim of this manual is to provide practical guidance to the medical community for medical emergency preparedness and response, describing the tasks and actions of different members of an emergency medical response organization within the national, regional or local medical infrastructure and in accordance with international guidance.

This manual provides generic response procedures for medical personnel responding to different types of radiation emergencies. Medical personnel includes:

1. Physicians and nurses responding at the pre-hospital level;
2. Physicians and nurses responding at the hospital level (performing general and specialized medical care);
3. Paramedical personnel responding at the pre-hospital and hospital levels; and
4. Personnel of the radiation protection support group including, but not limited to, a health/medical physicist and a decontamination team.

The manual covers procedures of medical response during the following types of radiation emergencies:

- Reactor emergencies (power and research reactors);
- Criticality emergencies;
- Emergencies involving lost or stolen dangerous sources;
- Emergencies resulting from use or misuse of dangerous industrial sources;
- Accidental medical overexposure;
- Transport and laboratory emergencies with involvement of radioactive material;
- Emergencies involvign malicious use of radioactive material; and
- Emergencies involving radioactive contamination of air, food products and water supplies.

The manual provides the tools, generic procedures, and data needed for initial medical response to radiation emergencies. It explains the roles and responsibilities of the members of the emergency medical response organization within the general response organization.

The procedures outlined in the manual are intended for use at the different stages of emergency response (at the scene of the emergency, pre-hospital, hospital), and during the early post-emergency stage (about 1–2 months afterwards). The manual is more focused on management aspects of medical response than on treatment protocols. Basic descriptions of medical treatment and of the clinical symptoms can be found in Diagnosis and Treatment of

Radiation Injuries (IAEA–WHO, Safety Response Series No. 2) [2]. The manual also addresses issues related to the public health response.

With regard to malicious acts involving radioactive material, this manual will address public health, medical, and psychological impact of such events. Emphasis will be directed to mass casualties and how generic procedures may be modified compared to radiation emergencies that typically result in a limited number of victims.

Procedures describe actions to be performed, consistent with the actions of other members of the generic response organization presented in the IAEA Refs. [3, 4, 5] and the EPR-Method [6].

1.3. STRUCTURE

This manual is organized in sections based on an assumed medical response structure (see Figure 01). Each section contains generic implementing procedures. Each procedure is organized in the order in which response actions will most likely be performed.

Section A provides generic procedures for response initiation, Section B deals with medical management procedures, Section C contains procedures describing the first steps of emergency medical personnel on scene at the emergency (at pre-hospital level), Section D deals with the steps at the hospital level, and Section E contains procedures for dealing with psychological consequences of the emergencies. Finally, Section F provides procedures necessary for dose assessment, and Section G describes the steps of public health response.

Necessary support information is provided in the Apendices. This manual also features sample worksheets to assist in data recording and information transfer.

NOTE

There are two ways to find the appropriate item in the manual, i.e. by referring to:

(a) the medical response organization by using Figure 01; or
(b) the Contents.

2. OVERVIEW

2.1. GOALS OF EMERGENCY RESPONSE

In a nuclear or radiological emergency, the practical goals of emergency response are [1]:

1. to regain control of the situation;
2. to prevent or mitigate consequences at the scene;
3. to prevent the occurrence of deterministic health effects in workers and the public;
4. to render first aid and manage the treatment of radiation injuries;
5. to prevent, to the extent practicable, the occurrence of stochastic health effects in the population;
6. to prevent, to the extent practicable, the occurrence of adverse non-radiological effects on individuals and among the population;
7. to protect, to the extent practicable, the environment and property; and
8. to prepare, to the extent practicable, for the resumption of normal social and economic activity.

Most of the goals are directly related to human health. Medical terminology is used even in some of the goal statements. Therefore, every medical and technical specialist participating in emergency response has to know and understand the meaning of the terms and the relation between radiation medicine, emergency medicine, physics and radiation protection.

2.2. GOALS OF EMERGENCY MEDICAL RESPONSE

The goals of medical response to nuclear or radiological emergency are:

1. to save lives and perform required emergency medical procedures;
2. to treat radiation injuries and injuries resulting from an emergency situation; and
3. to perform required public health actions, including public advice and councelling, and long term medical follow-up.

Actions of medical response need to be in line with the goals of emergency response.

2.3. RATIONALE

2.3.1. Preparedness for emergency medical response

In order to be effectively implemented, emergency medical response needs to be planned and organized in accordance with the potential consequences of different radiation emergencies. Being part of general emergency preparedness and response, medical response needs to take the same approach to planning as given in the international requirements for preparedness for and response to a radiation emergency for all response organizations [1, 6]. In general, before planning for emergency response, "…the practices and activities for which emergency response planning is necessary must be identified. Emergency planning could be different for each practice. However this could be simplified by grouping practices into five threat categories…each presenting common features in terms of the magnitude and timing of the hazard" [6]. Threat categories and examples of practices are presented in Table 01.

TABLE 01. FIVE CATEGORIES OF NUCLEAR AND RADIATION RELATED THREATS [1, 6]

Threat category	Description	Example practices
I	Facilities for which on-site events[1] (including very low probability events) are postulated that could give rise to severe deterministic health effects[2] off the site, or for which such events have occurred in similar facilities.	Large (> 100 MW(th)) reactors (power, research, ship), large storage of volatile reprocessing waste
II	Facilities for which on-site events[1] are postulated that could give rise to doses to people off the site that warrant urgent protective actions in accordance with international standards[3], or for which such events have occurred in similar facilities. Threat category II (as opposed to threat category I) does not include facilities for which on-site events (including very low probability events) are postulated that could give rise to severe deterministic health effects off the site, or for which such events have occurred in similar facilities.	Medium (2–100 MW(th)) reactors, spent fuel pool storage, reprocessing of spent fuel
III	Facilities for which on-site events are postulated that could give rise to doses that warrant or contamination that warrants urgent protective actions on the site, or for which such events have occurred in similar facilities. Threat category III (as opposed to threat category II) does not include facilities for which events are postulated that could warrant urgent protective action off the site, or for which such events have occurred in similar facilities	Small reactors (< 2 MW(th)), industrial irradiators, radiopharmaceutical manufacturing, hospitals utilizing sealed sources (brachytherapy or radiation beams), sealed sources manufacturing, fuel fabrication, dry spent fuel storage, reprocessing of spent fuel, users of large sources
IV	Activities that could give rise to a nuclear or radiological emergency that could warrant urgent protective actions in an unforeseeable location. These include non-authorized activities such as activities relating to dangerous sources obtained illicitly. Threat category IV represents the minimum level of threat, which is assumed to apply for all States and jurisdictions.	**Operators of mobile dangers sources:** industrial radiography, teletherapy, well logging **Operators of locations where dangerous sources may be found:** border crossing and large scrap metal processors **All States prepare for:** emergencies involving transport, abandoned, found, lost or stolen dangerous sources, detection of indication of a radiological emergency (e.g. medical symptoms), severe overexposures, notification of transnational emergency by IAEA, contamination of unknown origin; nuclear power satellite re-entry
V	Activities not normally involving sources of ionizing radiation, but which yield products with a significant likelihood[4] of becoming contaminated as a result of events at facilities in threat categories I or II, including such facilities in other States, to levels necessitating prompt restrictions on products in accordance with international standards.	Contamination from airborne release from threat category I, II within State or transboundary release, import of contaminated food or material

[1] Involving an atmospheric or aquatic release of radioactive material or external exposure (such as due to a loss of shielding or a criticality event) that originates from a location on the site.

[2] Doses in excess of those for which intervention is expected to be undertaken under any circumstances; see Schedule IV of Ref. [39], reproduced in Appendix 2. See Glossary under definition of deterministic health effects.

[3] Schedule V of Ref. [39], reproduced in Appendix 1.

[4] Conditional on the occurrence of a significant release of radioactive material from a facility in threat category I or II.

2.3.2. Types of radiation emergencies

From the medical response point of view, radiation emergencies could be classified on the basis of the following information required by medical personnel at the stage of preparedness in order to develop effective response capabilities:

- possibility of the occurrence of different health effects;
- possibility of contamination;
- number of people involved;
- where to expect appearance of injured people (on site, off site).

Table 02 represents different characteristics of possible health consequences for different types of emergencies.

A brief description of each emergency type is provided below.

2.3.2.1. Reactor emergencies

These emergencies may occur when breach of irradiated fuel elements occurs due to loss of coolant. If sufficient venting or failure of containment occurs, high doses may be received by on-site workers or members of the general public in the vicinity of the reactor. Widespread environmental contamination may occur and lead to external exposure of the general public from cloud or ground shine or to internal exposure from inhalation/ingestion of released radionuclides. Reactor emergencies may result in widespread non-radiological consequences including long lasting psychological effects.

2.3.2.2. Criticality emergencies

These emergencies may occur when sufficient quantities of special nuclear material are inadvertently allowed to undergo fission. Prompt, high level exposure is generally associated with the emergency, and persons in close proximity can receive very high doses. Workers more than about 10 metres from the assembly receive lower doses (it depends on circumstances, such as physical barriers or shielding). Members of the general public may also receive low doses due to neutron radiation.

2.3.2.3. Emergencies involving lost/stolen dangerous source

A lost or stolen source is a special case of emergency involving radioactive material. The risk to the public will depend mainly on the total activity involved and the length of time that people may be exposed to the source. It must be assumed that the source may be in possession of persons who do not know its nature and hazard, who may handle or break it resulting in contamination. Such emergencies can result in high doses to the whole body (WB) or localized body areas, and internal or external contamination. Serious injury or death may be a consequence of these emergencies.

2.3.2.4. Emergencies resulting from use or misuse of dangerous industrial sources

These emergencies may occur when proper industrial radiography procedures are not followed. Failure to use exposure control may lead to inadvertent overexposure to workers in the immediate work area. Touching the source for any reason often leads to serious injury to the hands. WB exposure in high doses may lead to death.

Emergencies at the industrial irradiation facilities most often lead to whole body exposure at high doses. Emergencies with involvement of mobile industrial radiography sources most probably lead to local radiation exposure.

TABLE 02. CHARACTERISTICS OF POSSIBLE HEALTH CONSEQUENCES FOR DIFFERENT TYPES OF RADIATION EMERGENCIES

Type of radiation emergency	**Effects related to radiation**					**Effects related to emergency**			**Combined trauma**	**Number of people involved**		**Effects will appear:**	
	deterministic		stochastic		contami-nation of persons	conventional trauma	psychological			limited	large	on-site	off-site
	ARS[5]	burns	detectable	non-detectable			limited	widespread					
Reactor (NPP, RR)	+/-[6]	+/-	+/-	+	+/-	+/-	-	+	+/-	+	+/-	+	+/-
Criticality	+/-	+/-	-	+	+/-	+/-	+	+/-	+/-	+	-	+	-
Lost/ stolen dangerous sources	+/-	+/-	-	+	+/-	-	+	+/-	-	+	+/-	+	+/-
Resulting from use or misuse of industrial dangerous sources	+/-	+/-	-	+	+/-	-	+	+/-	-	+	+/-	+	+/-
Misadministration in medical diagnosis and therapy	+/-	+/-	-	+[7]	+/-	-	+	-	-	+	-	+	-
Transport and laboratory	-	-	-	+	+/-	+/-	+	-	+/-	+	-	+	-
Malicious use of radioactive materials	+/-	+/-	-	+	+/-	+/-	-	+	+/-	-	+	+	+/-
Radioactive contamination of air, food products and water supplies	-	-	-	+	+	-	-	+	-	-	+	NA	+

[5] Acute radiation syndrome.
[6] "+" – expected, "-" – not expected, "+/-" depending on the scale of emergency.
[7] For internal application of sources.

2.3.2.5. Accidental medical overexposure

Accidental medical overexposure may occur because of miscalculation of the activity of a therapy source, improper function of an X ray device or accelerator, or when higher activities than intended are inadvertently administered during diagnosis and therapy. Although when a patient receives a lower dose than that prescribed by the physician, this can lead to a serious medical problem, this is not considered a radiation emergency, and such a situation is not considered in the manual.

2.3.2.6. Transport and laboratory emergencies with involvement of radioactive material

Many thousands of transport operations occur daily with the use of radiation and radioactive material. Transport can include road, rail, air, or sea modes. The spectrum of items transported varies greatly and includes nuclear industry products, radiography sources for industrial and medical use, gauges, and consumer products. The largest fraction of transport operations is associated with radiopharmaceuticals for medical use. The main problem with planning for transport emergencies is that they can occur anywhere and potentially affect the general public. Nevertheless, radioactive transport emergencies are, compared to all other categories, extremely rare. Moreover, transport packages are designed to resist different types of emergency situations (fire, pressure, etc). Therefore, even in an emergency, radioactive material will be intact if properly packed in accordance with the appropriate procedure.

Emergencies in laboratories (research or hospital) could have a potential for severe exposure to personnel due to external exposure and/or intake.

2.3.2.7. Emergencies involvingmalicious use of radioactive material

Emergencies involving malicious use of radioactive material can be divided into three categories or scenarios. These scenarios include the spread of sealed sources, use of a radiological dispersal device, or detonation of a crude or sophisticated nuclear weapon. Each scenario presents different aspects to be considered in emergency medical response. See Appendix X for details.

2.3.2.8. Emergencies involving radioactive contamination of air, food products and water supplies

Contamination of air, food products and water supplies could result from accidents (e.g. reactor emergency with outside release, damaged and dispersed lost or stolen dangerous source) or intentionally (malicious acts involving radioactive material (e.g. deliberate addition of radioactive material in food/water supply).

As a result of a reactor emergency, the contamination of food/products could lead to the low level exposure of a large number of people. Widespread public health action to restrict contaminated food consumption could be necessary. In the event of intentional contamination of food/products, significant exposure of large numbers of the public[8] is very unlikely. However, there is a potential for significant exposure to small numbers (e.g. contamination of products on store shelves) and to those working with or transporting the products/food. Contamination in excess of national and international trading standards for commodities is possible. Allowing contaminated or potentially contaminated products into the local, national, regional or international distribution system could have massive economic consequences.

[8] Resulting in early health effects or warranting long term medical screening.

Excess cancers ought not to be seen following this type of emergency, even if large amounts of radioactive material are involved.

2.3.3. Classification of casualties related to radiation emergencies

In a radiation emergency, victims may have been harmed by one or more of the following causes: external exposure (localized, partial and whole body), contamination (external/internal), and conventional trauma. All victims of a radiation emergency are to be assessed considering all these causes. The four categories of potential injury type are as follows:

2.3.3.1. Conventional injury

Conventional injuries could arise from other hazards, such as fires or steam leaks; or could result from mass panic actions (e.g. people running in the crowd). In malicious acts involving radioactive material, mass conventional injury may happen because of explosion/panic.

2.3.3.2. External exposure

External exposure occurs when an individual is exposed to radiation from a source outside the body. Personnel involved in the mitigation of an emergency or members of the general public may receive external doses ranging from low to very high, including lethal doses.

External exposure could be for the whole body, partial or localized. One of the most frequent consequences of localized external exposure is local radiation burn to the leg/hand of a radiographer from mishandling a sealed source, or to a member of the general public who has gained possession of a lost or stolen sealed source.

2.3.3.3. Contamination

Contamination occurs when radioactive material (solid, liquid or gas) is released to the environment. Workers, response personnel or members of the general public may become externally or internally contaminated following such release of radioactive material. High levels of external contamination with beta radionuclides could lead to severe radiation burns. High level of internal contamination could result in lethal dose and death of the person.

2.3.3.4. Combined injury

Combined injury is defined as conventional injury plus radiation exposure (external exposure/contamination), e.g. trauma with contamination of a wound suffered in the emergency.

2.3.3.5. Practical application of classification

These general categories could be subdivided into more specific groups for practical reasons and application during triage, as well as for planning the medical response and determining any special arrangements needed for equipment and supplies. These groups are as follows:

Persons with symptoms of radiation exposure

The most common early signs and symptoms of acute radiation exposure to a large body volume in high doses are nausea and vomiting. Except for very large doses, nausea and vomiting as a radiation exposure manifestation begin hours post-exposure. Radiation burns

have a latency period of days to weeks, so that immediate effects such as apparent burns to the skin will have other causes (chemical or thermal).

Some emergencies may not be discovered for days or weeks after the radiation exposure has occurred. This is especially true when members of the general public are involved or when, for one reason or another, workers fail to report events to the responsible authority.

Persons with combined injuries (radiation plus conventional trauma)

Treatment of such casualties has to be specific to the nature and grade of the combined injury. Whatever the case, radiation has the lowest priority. Combined injuries may worsen the prognosis of radiation exposure.

Persons with external/internal contamination

These individuals need to be monitored to assess the degree of contamination, if any. Decontamination facilities will be required. It is possible, but very unlikely, that contamination alone, without physical injury or a significant dose from external radiation, would be sufficient to have an acute effect on the casualty. Emergency responders utilizing proper contamination control have little chance of becoming contaminated during response in a contaminated environment. Decontamination is required to prevent or reduce further exposure, to reduce the risk of inhalation or ingestion of radioactive material, and to reduce the spread of contamination.

Persons with potential radiation symptoms

Casualties do not require immediate medical treatment but do require urgent evaluation of the levels of dose. Because of this, medical staff needs to have sufficient knowledge, procedures, equipment and supplies to perform the first biological and medical examinations and analysis necessary immediately after arrival at hospital in order to perform medical triage of potential radiation injuries.

Unexposed persons with conventional trauma

Casualties needs to be taken to a specialized hospital where their medical treatment can be delivered in accordance with their needs.

Persons believed to be uninjured and unexposed

All persons known to be uninjured and unexposed need to be allowed to return to their own homes (or suitable civilian reception/evacuation facility if movement restrictions do not permit this). The registration of all persons living or working within the immediate vicinity of an emergency may be required in order to facilitate proper medium to long term re-assurance and to avoid false claims after the emergency.

Persons requiring counselling for psychological stress

All individuals involved in response to radiation emergencies, the victims, and members of the general public may experience varying degrees of psychological distress. Such distress may present at any time following the event. The magnitude of distress can be greatly increased when the radiation emergency is the result of a malicious act involving radioactive material. Adequate support must be timely provided by trained, experienced professionals. The potential danger to medical response from this category of people in the case of a malicious event could be in the overwhelming of medical facilities, as such people will seek medical advice and help believing their health to be threatened.

2.4. GENERAL CONCEPT OF MEDICAL RESPONSE

The response to a radiation emergency and the medical care for individuals involved depend to a large extent on factors associated with the emergencies, such as the type of the emergency, i.e. whether the individuals have been exposed to external sources of radiation or contaminated with radioactive material; the number of victims; and the association and severity of conventional injuries. The same general principles of medical care apply at the scene of the emergency as at hospital, but the details and extent of medical care differ.

The responders to a radiation emergency must have confidence that when they follow appropriate procedures, there will be no consequences to them, either directly or indirectly, as a result of providing care for victims. This confidence must also be conveyed to the victims themselves. The responders need to be aware that if an individual has only been exposed to only external sources of radiation, there is no radiation threat whatsoever to them and those precautions are not needed in patient handling and care.

If individuals are contaminated only internally as a result of inhalation or ingestion of radioactive material, then they do not present a direct hazard of external exposure to others, unless the intake was extremely large and involves gamma emitters. However, contaminated excreta or vomit can spread contamination to equipment, environment, and attending staff. Using appropriate procedures could prevent spreading of contamination.

2.4.1. Threat description and concept of operations

Each of the threat categories includes possible medical consequences that could be used as a basis for planning medical response. This section provides a brief description of possible medical effects for each threat category. The desired response is described in the concept of operations for emergencies within threat categories.

2.4.1.1. Threat category I and II facility emergencies

Threat description

Possible effects:

- deterministic effects (e.g. ARS, radiation burns) among emergency workers, personnel and population;
- stochastic effects (e.g. cancers), for which the chance of being detected depends on the size of affected population and dose level;
- contamination of individuals (on-site and off-site);
- psychological impact.

For these emergencies and other general emergencies at threat category I and II facilities, direct contamination of food and open water supplies may occur at a considerable distance.

Concept of operations

Emergency medical personnel provide medical assistance to the site, if requested. People from on site who are contaminated or exposed above predetermined criteria are transported to local hospitals and treated in accordance with procedures. Physicians treating exposed individuals consult doctors with experience in dealing with severe overexposures. National officials support local officials and assist in obtaining specialized treatment of exposed persons through the IAEA and WHO under the Assistance Convention [7, 8] if necessary. Triage centres are established within 24 hours outside the evacuated area to screen casualties and determine the level of treatment for the overexposed public and on-site personnel. People who

are contaminated or exposed above predetermined criteria are assigned to predetermined and prepared hospitals located outside the affected area.

Public health specialists are involved in recommending the appropriate protective and other actions on the basis of predetermined criteria. Appropriate medical specialists will provide information, advice and counselling to the public. The personal data of people in a population with exposures due to the emergency sufficient to result in detectable excess cancer incidence among the exposed population will be placed on a registry[9]. Those on the registry will receive information on their individual risk and long term medical screening to early detect and effectively treat any cancers if they do occur.

2.4.1.2. Threat category III facility emergencies

Threat description

Possible effects:

- deterministic effects (e.g. ARS, radiation burns) among emergency workers, personnel and individuals (for medical overexposure);
- stochastic effects (e.g. cancers), with virtually no chance of being detected, as the population affected is usually very limited;
- contaminated individuals (on-site);
- psychological impact.

These emergencies may lead to the risk of contaminated persons, products, articles or equipment leaving the site.

Concept of operations

Emergency medical personnel provide medical assistance to the site, if requested. If there are serious overexposures, the facility staff gathers information concerning the circumstances and other information helpful for reconstructing the dose. Contaminated or overexposed persons, identified on the basis of predetermined criteria, are transported to local hospitals and treated there in accordance with advanced training and procedures. Physicians treating exposed individuals consult doctors with experience in dealing with severe overexposures. National officials support local officials and assist in obtaining specialized treatment of exposed persons through the IAEA and WHO under the Assistance Convention [7, 8] if necessary.

Public health specialists are involved in recommending the appropriate protective and other actions on the basis of predetermined criteria. Appropriate medical specialists will provide information, advice and counselling to the public.

2.4.1.3. Threat category IV radiological emergencies

Threat description

Possible effects:

- deterministic effects (e.g. radiation burns, ARS) among personnel, population and emergency workers;
- stochastic effects (e.g. cancers), with virtually no chance of being detected, as the population affected is usually very limited;
- contaminated individuals (on-site and off-site);
- widespread psychological impact.

These emergencies may lead to direct contamination of food and open water supplies.

[9] For the purpose of early diagnosis and effective treatment of radiation-induced cancer. People need to be informed of practical purpose of registration. They also need to be informed if any scientific use of data is planned.

Concept of operations

For these emergencies, planning at the local level is limited to being able to recognize a potential radiological emergency (e.g. recognizing clinical symptoms of radiation exposure), being familiar with basic precautions and knowing who should be called to provide further assistance.

Physicians recognizing radiation-induced injuries have been the first to alert response officials of many, if not most, emergencies involving lost or stolen sources. As such emergencies are very rare, local physicians are inexperienced in the diagnosis of these injuries. Actions are needed to be taken at the preparedness stage that physicians will become fully aware of the possible symptoms of radiation overexposure in order to start earlier treatment and trigger the general response.

In a case of serious overexposure, interviews are conducted, photographs are taken and other information needed to estimate the dose is gathered at the scene. Medical examinations and blood tests are promptly performed to assist in estimating the dose. A course of treatment, based on the estimated dose received, is established in consultation with the experts. The decision on treatment takes both the physical and psychological suffering of the patient into consideration. National officials provide advice to local officials and dispatch personnel/teams to assist with arrangements for effective medical treatment. If additional assistance is needed, national officials need to request it through the IAEA and WHO under the Assistance Convention [7, 8].

Potentially contaminated individuals are monitored and, if necessary, decontaminated. If they need hospitalization, they are accompanied by somebody who can provide monitoring and advice on radiation to the hospital. If this is not possible, the hospital is given technical information on control of contamination by the operator or radiation protection officer (radiological assessor).

Public health specialists are involved in recommending the appropriate protective and other actions on the basis of predetermined criteria. Appropriate medical specialists will provide information, advice and counselling to the public.

For emergencies involving contaminated products, a decision should be made on restriction of food consumption.

2.4.1.4. Threat category V radiation emergencies

Threat description

Possible effects:

- stochastic effects (e.g. cancers), with possibility of being detected depending on the size of affected population and dose level;
- psychological impact.

For these emergencies direct contamination of food and contamination of water supplies may occur at a considerable distance. The Chernobyl accident resulted in contamination exceeding the international guidance on food restriction at more than 1000 km from the plant site.

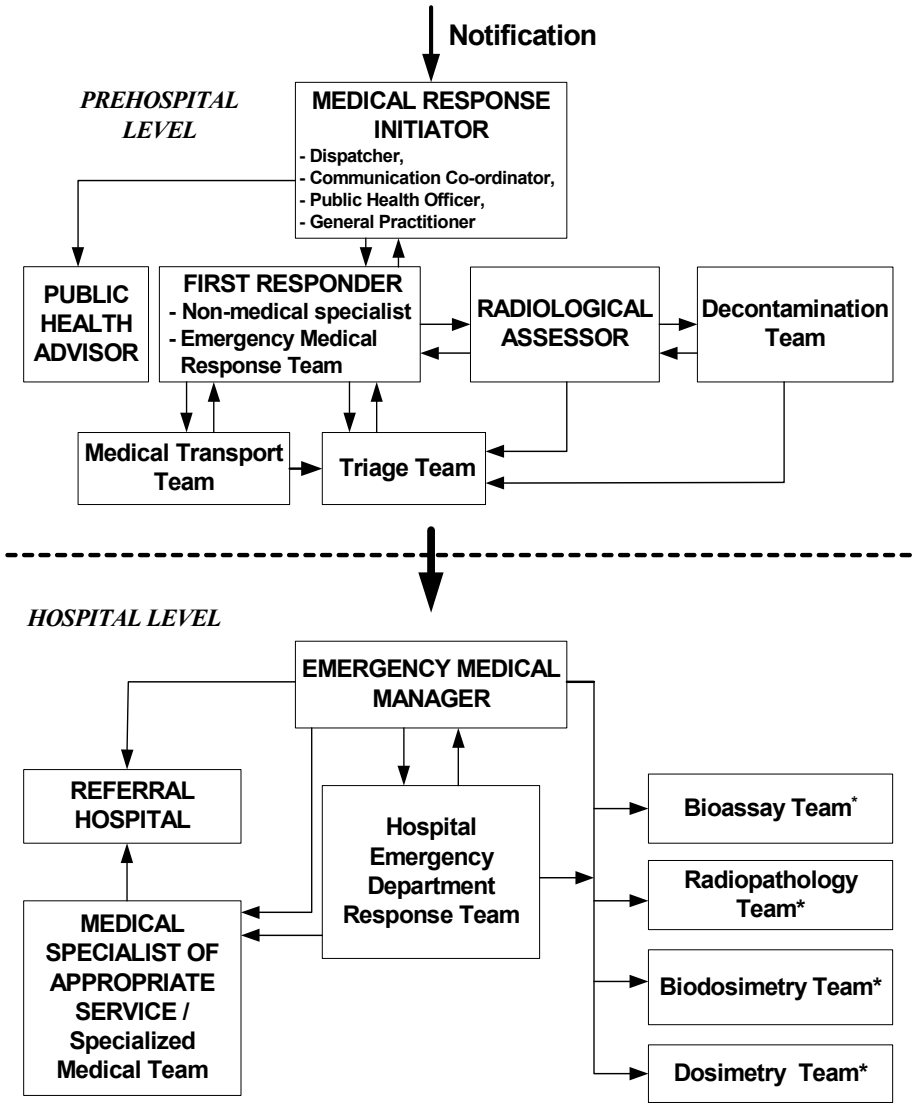
Concept of operations

Public health specialists are involved in recommending the appropriate protective and other actions on the basis of predetermined criteria. Appropriate medical specialists will provide information, advice and counselling to the public. The personal data of people in a population with doses of exposure due to the emergency sufficient to result in detectable excess radiation-

induced cancer incidence among the exposed population will be placed on a registry[9]. Those on the registry will receive information on their individual risk and long term medical screening to early detect and effectively treat any cancers if they do occur. If additional assistance is needed, national officials need to request it through the IAEA and WHO under the Assistance Convention [7, 8].

2.5. MEDICAL RESPONSE ORGANIZATION IN RADIATION EMERGENCY

The structure of medical response organization in a radiation emergency is presented on Fig.01. Each of the positions (functions) presented in the Figure is discussed below.



* – If the hospital does not have Bioassay, Radiopathology, Biodosimetry, and Dosimetry Teams the hospital needs to obtain assistance within the country and/or request assistance at the international level through the IAEA and/or WHO [7, 8, 9]. The Ministry of Health should be aware of the procedure on how to request the assistance.

FIG. 01. Medical response organization in radiation emergency

2.5.1. First responder

The First Responder is the first person or team to arrive at the scene of an emergency with the official role to play in the emergency response [5].

For example, at a facility where radioactive sources, radioactive material, or radiation generators are used, the First Responder might be the Radiation Protection Officer. For an emergency in a public place, the First Responder would likely be one of the emergency services, i.e. police, fire service, or emergency medical responders. The First Responder is responsible for dealing with all aspects of the emergency at the scene. They are also responsible for providing first aid for injured persons using standard methods for medical first aid (if qualified) until arrival of the Emergency Medical Response Team.

2.5.2. Medical response initiator

A Medical Response Initiator is the person who initiates the formal emergency response (medical or general) after notification of a real or suspected radiation emergency.

The role of the Medical Response Initiator could be taken by the Dispatcher or Communication Coordinator, who initiates the emergency medical response at the pre-hospital and hospital level accordingly.

In the case of public health response initiation, it will be done by a Public Health Officer of the local or national level.

If the event is recognized by a general practitioner or any other medical specialist following examination of a casualty, this physician will have the responsibility to act as the Medical Response Initiator and initiate a general emergency response.

In the hospital, a designated Communication Coordinator will act as the Medical Response Initiator.

The Medical Response Initiator is responsible for obtaining basic information characterizing the emergency and notifying the appropriate level of response. At the pre-hospital level, the Emergency Medical Responder are to be notified and alerted. At the hospital level, the Emergency Medical Manager are to be notified. In the case of public health response initiation, emergency response personnel and decision makers are to be alerted in accordance with the existent system of emergency response. In the case of need for general response initiation, the Medical Response Initiator should notify the head of the organization where he/she is working.

2.5.3. Emergency medical response team

The Emergency Medical Response Team is the specialized medical team coming to the scene of the emergency upon notification. It is responsible for providing first aid to casualties. Members of the team should have knowledge of emergency medicine, the basic biological effects of ionizing radiation, and radiation protection. The role of Emergency Medical Responders in some countries may be performed by qualified paramedical personnel.

2.5.4. Emergency medical manager

The Emergency Medical Manager is a specialist (may be a nurse administrator) working in the hospital. They start to respond at the hospital level upon notification of the arrival of the casualties. The Emergency Medical Manager is responsible for managing the actions of the Hospital Emergency Department Response Team, the Medical Specialist of the appropriate

service, the Health/Medical Physicist, and the Radiation Protection Support Group. They manage the implementation of the decision to send the patient to the referral hospital.

The role of Emergency Medical Manager could be taken by the head of the hospital, team Coordinator or Emergency Physician (in the absence of team Coordinator) from the Hospital Emergency Department Response Team.

2.5.5. Medical transport team

The Medical Transport Team is responsible for transporting the casualties from the scene of the emergency to the Emergency Department of the hospital. The members of the team should know how to deal with injured persons during transportation. They need to be trained in contamination control procedures.

In some countries, a physician or paramedic is a member of the ambulance team arriving at the scene of the emergency. After actions on the scene, medical/paramedical personnel will accompany the casualty during ambulance transportation.

2.5.6. Hospital emergency department response team

The Hospital Emergency Department Response Team is a group of specialists and support personnel from the hospital. The team is activated upon notification that casualties will arrive at the hospital. Ideally the team will include a team Coordinator, Emergency Physician, Triage Officer, Nurse, Technical Recorder, Public Information Officer, Security Personnel, Laboratory Technician, and Maintenance Personnel.

The Hospital Emergency Department Response Team is responsible for accepting the casualty in the prepared reception area, assessing the patient’s medical status and providing necessary treatment. The Emergency Physician will make a decision about maintaining the patient in the appropriate services of the hospital or removing him/her after clinical stabilization to the Referral Hospital directly. The Radiation Protection Support Group will work jointly with the Hospital Emergency Department Response Team.

The work of the Hospital Emergency Department Response Team is coordinated by the Emergency Medical Manager.

In some cases, the Hospital Emergency Department Response Team can have fewer members as long as all responsibilities are covered.

Each member of the team should be familiar with the hospital's emergency plan and should be trained in scheduled drills.

2.5.7. Medical specialist of appropriate service (Specialized medical team)

They are a medical specialist with qualifications in accordance with the speciality of the service (e.g. traumatologist, surgeon, haematologist, etc). They are responsible for providing the necessary treatment for the patient, taking into account possible external/internal contamination. They need to follow the procedures of the hospital plan for medical response to radiation emergencies in dealing with patients injured by radiation emergency. The Medical Specialist of the appropriate service is responsible for decisions about transferring the patient to a Referral Hospital after clinical stabilization in the appropriate service of the hospital.

The work of the Medical Specialist of the appropriate service is coordinated by the Emergency Medical Manager.

2.5.8. Referral hospital

The Referral Hospital is a specialized hospital with personnel experienced in dealing with patients injured by radiation. It could be located in or outside the country, in which case response could be coordinated through the IAEA or the REMPAN system of WHO [9, 10]. The Referral Hospital is responsible for providing the patient with highly qualified treatment. Patient care in the Referral Hospital could last a long time, depending on the patient's condition. This long term procedure is not covered in this manual.

2.5.9. Public health advisor

The Public Health Advisor is the official working in the appropriate Public Health Service at the local or national level. The Role of the Public Health Advisor in a radiation emergency is to notify the public about possible threats and initiate the response. Initiation of stable iodine prophylaxis and procedure for establishing long term medical follow-up are high priority tasks for the Public Health Advisor.

2.5.10. Radiological assessor

This position will normally be held by the most senior member of the team(s) of radiological professionals (qualified experts) sent to the scene of an emergency to assess the radiological hazards, provide radiation protection for the First Responder, Emergency Medical Response Team and other responders on scene [5].

The Radiological Assessor may be alone or part of a team. They are responsible, among other tasks, for surveys, contamination control, and arranging decontamination operations (if necessary to be performed on scene) among injured persons.

2.5.11. Health/medical physicist

The Health/Medical Physicist is the specialist working at the hospital and acting at the hospital level within the emergency medical response. They have knowledge and experience in dose assessment, radiological survey, rapid screening of contamination, and decontamination of the patients. They are the 'Radiological Assessor' at the hospital level. They will supervise and direct external contamination monitoring in the reception area of the Hospital Emergency Department, in the appropriate service of the hospital; and may assist in decontamination of external contamination under the supervision of a medical specialist.

The Health/Medical Physicist is usually a member of the Dosimetry Team.

2.5.12. Decontamination team

The Decontamination Team conducts personal and equipment contamination monitoring on the scene of an emergency. This team will assist emergency medical response personnel with personal monitoring of the injured people and prevention of the spread of contamination. Decontamination preocedures are not recommended at the scene, except simple procedure of removal external cloth for non-seriously injured victims. The team acting on scene usually does not include specialists qualified for special decontamination of wounds, eyes, ears and body orifices.

The Decontamination Team on scene usually has tasks and responsibilities in addition to those associated with monitoring and decontamination. This team is part of the generic response organization and the generic environmental/source monitoring organization, in particular. For the details about actions on scene, see TECDOC-1092, TECDOC-1162 and ERNET manual [4, 5, 9].

Team members need to be skilled in the use of radiation monitors to assess contamination of the skin and clothing, to prevent the spread of contamination and to monitor the efficiency of decontamination procedures. They have to be skilled in safe disrobing techniques as well as thyroid measurement (screening).

The Decontamination Team acts in co-operation with the Radiological Assessor.

2.5.13. Triage team

The Triage Team performs triage at the scene of an emergency with a large number of victims (what is considered to be a large number of victims depends on arrangements in a specific country). For a limited number of victims, triage is usually done by the Emergency Medical Response Team.

2.5.14. Bioassay team

The Bioassay Team* is a specialized team with expertise in the following: in-vitro and in-vivo bioassay; personnel internal contamination monitoring techniques; interpretation of bioassay data, biokinetic modeling from individual retention data, ICRP biokinetic models, individual dose assessment methodologies using bioassay data; and radiation protection.

The Bioassay Team of the hospital needs to be able to: identify and determine levels of specific radionuclides using in-vivo bioassay techniques (whole body and organ counting and external counting at wound sites); identify and determine levels of specific radionuclides in body excreta and in other biological materials such as nasal swabs, hair, blood; interpret the data in terms of committed effective dose, using appropriate models such as those of the IAEA or the ICRP, or individual retention functions; and to interpret data during decorporation treatment, evaluate its efficiency, and assess committed doses taking treatment into consideration.

The Bioassay Team works in co-operation with the Hospital Emergency Department Response Team and the Medical Specialist of the appropriate service. The work of the Bioassay Team is coordinated by the Emergency Medical Manager.

2.5.15. Radiopathology team

The Radiopathology Team* is a specialized team with expertise in radiopathology and basic radiation protection. The Radiopathology Team of the hospital should be able to obtain the appropriate tissue samples through biopsy or autopsy procedures; prepare samples for histopathological analysis; and conduct the evaluation of the samples.

The Radiopathology Team works in co-operation with the Hospital Emergency Department Response Team and the Medical Specialist of the appropriate service. The work of the Radiopathology Team is coordinated by the Emergency Medical Manager.

2.5.16. Dosimetry team

The Dosimetry Team* of the hospital conducts personal and equipment contamination monitoring at the hospital level, decontamination of the patients and assessment of decontamination efficiency in the hospital. In some cases, the hospital may ask the Decontamination Team acting on scene to escort casualties to the hospital and to perform decontamination there.

The Dosimetry Team is responsible for complete dose evaluation for the patient, taking into account data provided by the Bioassay Team, the Radiopathology Team, the Biodosimetry Team, and relevant information on environmental measurements. The team is also responsible

for providing data on dose assessment to the medical personnel in order to make necessary corrections in the treatment and conclude on prognosis of the patient status and surveillance.

The Health/Medical Physicist is usually a member of the Dosimetry Team.

The work of the Dosimetry Team is coordinated by the Emergency Medical Manager.

2.5.17. Biodosimetry team

The Biodosimetry Team* is a specialized team with expertise in biological dosimetry, basic radiation protection, and human radiation cytogenetics. This team will assist in patient dose assessment using specialized cytogenetic procedures. Typically, the Biodosimetry Team is not routinely a component of most hospitals but is accessed as a referral team from national or international resources.

The Biodosimetry Team works in co-operation with the Hospital Emergency Department Response Team and the Medical Specialist of the appropriate service. The work of the Biodosimetry Team is coordinated by the Emergency Medical Manager.

SECTION A
RESPONSE INITIATION

Caution: *The procedures in this section should be adapted to reflect national, local and hospital conditions and capabilities for which they will be applied.*

Performed by: *Medical Response Initiator*	**PROCEDURE A0** **EMERGENCY MEDICAL RESPONSE INITIATION OVERVIEW**	*Page 1 of 2*

Purpose

To provide an overview of formal emergency medical response initiation upon notification of a radiation emergency or recognition/suspicion of radiation injury.

Discussion

In a nuclear emergency, medical responders will be notified by the appropriate response organization. After receiving a phone call at the local/national level, the emergency medical response organization must be activated to the extent required for the magnitude of the emergency.

In a radiological emergency, initiation of the response will depend on who detected the event. If the event was detected by an organization other than medical, the local/national level of emergency medical response organization will be notified. If the event is detected by a general practitioner or other physician upon investigation of the patient, the general response will be triggered by medical specialists.

Therefore, different responsible persons can act as Medical Response Initiator. The role of the Medical Response Initiator could be taken by the Dispatcher or Communication Coordinator, Public Health Officer, and by a general practitioner.

Input

- Notification of a radiation emergency situation with injured people;

or

- Recognition/suspicion of radiation injury.

Output

- Activated emergency medical response at the appropriate level;

or

- Activated general emergency response.

Step 1

Upon notification, obtain basic information about the emergency, casualties, and possible threats to the public.

NOTE

If a malicious act involving radioactive material is known or suspected, local, state, or national authorities must be notified. If the nature of the malicious act is known, details must be shared with the proper authority.

Step 2

Depending on your position and necessity to activate the emergency medical response at different levels, use the following procedures:

Position:	Procedure
Dispatcher	A1
Communication Coordinator	A2
General Practitioner	A3
Public Health Officer	A4

Performed by: *Dispatcher*	**PROCEDURE A1** **INITIATION OF PRE-HOSPITAL RESPONSE**	*Page 1 of 1*

Purpose
To provide guidance to initiate formal emergency medical response at the pre-hospital level upon notification of a radiation emergency with casualties.

Discussion
This procedure is to be known and followed by all members and staff of emergency medical services (ambulances, first aid services, etc.) who may be the first notified of a radiation emergency with casualties, acting as a Dispatcher of the emergency medical service.

Input
- Notification of a radiation emergency situation with casualties.

Output
- Activated response of the emergency medical service;
- Emergency Registration Form (Worksheet A1).

Step 1
Obtain emergency description from the reporting person using Emergency Registration Form (Worksheet A1). Verify the call.

Step 2
Advise the caller to take the following actions, if applicable:
(i) Wait for Emergency Medical Response Team and Medical Transport Team.
(ii) Provide first aid if qualified.

Step 3
Make a decision about the number of Emergency Medical Responders and Medical Transport Teams needed.

Step 4
Alert the Emergency Medical Responder(s) and Medical Transport Team(s). Inform team leaders if malicious acts involving radioactive material are known or suspected.

Step 5
Inform the Emergency Medical Responder(s) and Medical Transport Team(s) about the emergency situation. Provide them with information registered in Worksheet A1.

Step 6
Advise the Emergency Medical Responder(s) and Medical Transport Team(s) on necessary precautionary actions and/or protective equipment using available information on emergency.

Step 7
Provide Worksheet A1 for Public health officer (if applicable by nature and magnitude of the event).

Step 8
Record all your actions in a logbook.

Performed by:	**PROCEDURE A2**	*Page 1 of 1*
Communication coordinator	**INITIATION OF HOSPITAL RESPONSE**	

Purpose
To provide steps to initiate formal emergency medical response at the hospital level upon notification of arrival of casualties due to radiation emergency.

Discussion
According to the emergency response plan, hospitals need to be notified about the arrival of victims. After receiving notification, a planned course of action should be followed.

Input
- Notification of arrival of casualties due to radiation emergency.

Output
- Activated emergency medical response at the hospital level;
- Emergency Victim Registration Form (Worksheet A2).

Step 1
After receiving the phone call, get information from the reporting person using Emergency Victim Registration Form (Worksheet A2), including the following:

(i) Number of victims.
(ii) Each victim's medical status and type of injury.
(iii) If victims have been surveyed for contamination.
(iv) Radiological status of victims (exposed vs. contaminated).
(v) Identity of contaminant, if known.
(vi) Estimated time of arrival.

If the emergency notification comes from a source other than usual emergency communications, get a call-back number and verify the call prior to assembling the Emergency Response Team and preparing for patient admission.

Step 2
Assume victims are contaminated until proved otherwise. Advise ambulance personnel of any special entrance to the emergency department for the radiation emergency victim.

Step 3
Alert the Emergency Medical Manager and provide him/her with Worksheet A2.

NOTE

It is essential that this step is undertaken earlier in mass casualty radiation emergencies when services to many sites need to be carefully coordinated to ensure both response to the emergency and the continued provision of effective health care services to the population not immediately affected by the emergency. If there is widespread pubic concern, arrangements should be made to alert local medical facilities of the potential for arrival of concerned people.

Step 4
Record all your actions in the logbook.

Performed by:	**PROCEDURE A3**	*Page 1 of 1*
General practitioner	**INITIATION OF GENERAL EMERGENCY RESPONSE**	

Purpose

To provide guidance for physicians to initiate general emergency response upon detection of radiation injury.

Discussion

This procedure is to be known and followed by general practitioners (physicians). There are cases when radiation injury is recognized early by a physician, and then response to an event started. Therefore, prompt and effective response to the event could be associated with radiation injury recognition by general practitioners and other physicians. Physicians should be aware of the possibilities of such cases and know what needs to be done. Guidance regarding recognition of radiation injury can be found in the IAEA–WHO leaflet on *How to recognize and initially respond to an accidental radiation injury* (Could be downloaded from the IAEA website: http://www-pub.iaea.org/MTCD/publications/PDF/IAEA-WHO-L-Eng.pdf).

Input

- Recognition/suspicion of radiation injury.

Output

- Activated general emergency response.

Step 1

Draw a conclusion about unknown injury based on history and physical examination of the patient.

NOTE

Victims of undetected malicious acts involving radioactive material will generally seek medical assistance only when signs and symptoms appear. These signs and symptoms may lead to misdiagnoses since there is no unique disease associated with radiation exposure. Therefore, it could lead to the malicious event staying unrecognized. Clusters of individuals with similar signs and symptoms need to be reported to health authorities.

Step 2

Perform all necessary examination and tests for determination of the unknown injury, taking into account the possibility of radiation injury.

Step 3

If radiation injury is suspected, consult with appropriate specialists.

Step 4

If radiation injury is confirmed, inform the Head of the Medical Service (or other appropriate responsible person) of your institution to activate the general emergency response.

NOTE

It is essential that this step is undertaken earlier in mass casualty radiation emergencies when services to many sites need to be carefully coordinated to ensure both response to the emergency and the continued provision of effective health care services to the population not immediately affected by the emergency.

Performed by: *Public health officer*	**PROCEDURE A4** **INITIATION OF PUBLIC HEALTH RESPONSE**	*Page 1 of 1*

Purpose

To provide guidance to initiate formal emergency medical response at the local/national level upon notification of nuclear or radiological emergency with possible threat to the public.

Discussion

This procedure is to be known and followed by appropriate staff of official medical response organizations at the local and national level which need to be notified of possible threat to public health in a nuclear emergency.

For nuclear reactor emergencies, in most countries medical officials will be involved in making the decision on administration of stable iodine in the case of possible impact of radioactive iodine. In some countries, a decision can be made at the local level without involvement of national medical authorities; in others, only after a decision at the national level. For radiological emergencies, medical officials will be involved in providing information, advice and councelling to the public. Known or suspected by medical officials events of malicious acts involving radioactive material should involve national authorities as soon as possible.

Input

- Notification of a real or potential nuclear or radiological emergency with potential threat to the public.

Output

- Activated emergency medical response for stable iodine administration;
- Activated emergency medical response for other public guidance (to the extent agreed in national /local emergency plan);
- Programme for long-term medical follow-up;
- Emergency Registration Form (Worksheet A1).

Step 1

Obtain emergency or accident description from the reporting person using Emergency Registration Form (Worksheet A1). Verify the call.

Step 2

Alert Public Health Advisor and provide him/her with basic information on emergency situation using Emergency Registration Form (Worksheet A1).

NOTE

It is essential that this step is undertaken earlier in radiation emergencies with mass casualties when the services to many sites need to be carefully coordinated to ensure both response to the emergency and the continued provision of effective health care services to the population not immediately affected by the emergency.

Step 3

Record all your actions in the logbook.

SECTION B

MANAGING EMERGENCY MEDICAL RESPONSE

Caution: *The procedure in this section should be adapted to reflect national, local and hospital conditions and capabilities for which they will be applied.*

Purpose

To provide steps with basic actions of the Emergency Medical Manager to be performed at the hospital level in a radiation emergency.

Discussion

The Emergency Medical Manager assesses the situation immediately on the basis of information from the Medical Response Initiator of the hospital. If the hospital was not notified in advance by the Medical Transport Team and casualties have already arrived, the Emergency Medical Manager assesses the situation accordingly. He/she needs to manage the response of the hospital specialists, the implementation of the decision to transfer casualties to the Referral Hospital, and provide the information for the official channels inside the country. He /she needs to have constantly updated information about changes in patient conditions and progress of the response in the hospital.

Input

- Information about the victims of the emergency:
  - from Worksheet A2 (if it was filled out from phone call information);
  - from responsible person (if the patient has arrived without previous notification).

Output

- Activation of the Hospital Emergency Department Response Team;
- Briefing of the Hospital Emergency Department Response Team;
- Initiation for preparation of the ambulance reception and treatment area;
- Establishment of information line with official authorities.

Step 1

Obtain briefing from the Medical Response Initiator or any other specialist already involved in the response at the reception area (if the patient just arrived). Activate Hospital Emergency Department Response Team and Radiation Protection Support Group of the hospital.

NOTE

In a case of a malicious act involving radioactive material or other emergency resulting in mass casualty, implement provisions to assess the concerns of members of the public (worried-well) who are worried about radiation exposure outside the hospital admitting radiation casualties. Consider establishing secondary assessment centres at easily accessible sites such as athletic fields, stadiums, and community centres.

NOTE

In the event of a radiation emergency involving a large number of contaminated casualties, consider the use of a pre-reception area for radiological triage and decontamination of patients (if their medical conditions allow it).

Step 2

Issue an order for necessary preparation of ambulance reception area and treatment area.

Step 3
Start a personal log to record critical actions and decisions made during emergency medical response at the hospital level.

Step 4
Make sure that all necessary personal protection guides and actions are implemented in accordance with the hospital emergency response plan.

Step 5
Ensure that members of the Hospital Emergency Department Response Team and other medical and support personnel of the hospital are aware of the potential need for rapid media response. Ensure that the Public Information Officer from the Hospital Emergency Department Response Team has been notified and has started to fulfil their responsibilities.

NOTE

The Public Information Officer has the following tasks:
- Provide factual information about the organization's role in the emergency;
- Provide factual information about the condition and treatment of patients (bearing in mind their right to confidentiality);
- Ensure close liaison with the media so that staff are not interrupted in their response, and patients and relatives are not pestered.

The Public Information Officer will need to liase with colleagues in other agencies, e.g. police, fire, other medical bodies, utilities, transport operators and local authorities.

Step 6
Ensure that systems of communication are established with the national health authority/agency responsible for the strategic and tactical medical management of the emergency.

NOTE

It is essential that this step is undertaken early in mass casualty radiation emergencies when the services to many sites need to be carefully coordinated to ensure adequate response to the event and the continued provision of effective health care services to the population not immediately affected by the emergency.

Step 7
Regularly obtain briefing about the response in the hospital from the responsible persons.

Step 8
Ensure that all actions, decisions and/or recommendations have been registered in the logbook.

Step 9
After termination of the response in the hospital convene meeting of all participants to evaluate the response and sum up lessons identified. Recommend suggestions for updating the Hospital plan for Medical Response to Radiation Emergencies.

SECTION C

RESPONSE AT THE SCENE (AT PRE-HOSPITAL LEVEL)

Caution: *The procedures in this section should be adapted to reflect national, local and hospital conditions and capabilities, including protocols of medical treatment for which they will be applied.*

Performed by:	**PROCEDURE C1**	
First Responder(s)	**ACTIONS ON SCENE UNTIL ARRIVAL OF EMERGENCY MEDICAL RESPONSE TEAM**	*Page 1 of 2*

Purpose
To provide guidance to the First Responder(s) on actions to be taken on scene until arrival of Emergency Medical Response Team.

Discussion
Until the arrival of Emergency Medical Response Team on the scene, First Responders (Facility Responder, police, fire service, or other personnel who have been adequately trained in techniques of basic first aid) can provide emergency first aid for injured person(s). Radiation exposure or contamination with radioactive material does not cause immediate signs or symptoms and, therefore, if victims are unconscious, disoriented, burned, or otherwise in distress, look for causes other than radiation.

Input
- Emergency situation with casualties.

Output
- First aid performed at the scene.

Step 1
Note conventional hazards in the area (fire, smoke, steam, chemicals, electrical hazards, etc.). Search for casualties. If available, use monitoring devices to assess radiation hazards.

CAUTION

When responding to a known or suspected malicious act involving sealed sources, do not handle or otherwise come in contact with these sources. As long as the sources are intact, there is no contamination hazard. Exposure hazards are diminished by avoiding close proximity to any sealed source.

In a case of nuclear weapon detonation, anticipate radiological as well as conventional hazards, which must be considered before any medical care can be offered.

Step 2
Call for Emergency Medical Response Team and indicate situation and location (if was not done yet).

Step 3
If area is free of conventional hazards, check victims' condition. If there is immediate life-threatening hazard in the area, remove victim first.

Step 4
Apply standard first aid procedures.

NOTE

Life-saving procedures, including cardiopulmonary resuscitation (CPR), control of haemorrhage, and fracture stabilization are to be performed only by those personnel specially trained, since attempts to perform these actions by non-trained personnel may only complicate victims' condition.

Step 5

Do not move victims with severe injuries unless there is a life-threatening hazard in the area (such as fire).

NOTE

If a victim has spinal fracture or life-threatening injuries, movement may aggravate his/her condition more than would the hazardous situation.

Step 6

Stay with victims until help arrives.

Step 7

Brief the Emergency Medical Response Team.

Purpose
To provide guidance on emergency medical response under radiological conditions for the Emergency Medical Response Team.

Discussion
The Emergency Medical Response Team will most likely arrive on the scene shortly after notification of a radiation emergency. On-scene Controller should take charge of general response [5]. First aid actions may be in progress by First Responders.

Input
- Notification of an emergency;
- Assessment of situation at the scene.

Output
- Response actions at the scene in accordance with the results of medical and radiological triage.

Step 1
Get briefing by the On-scene Controller upon arrival. Consider areas established by first responders (Figure C1 [6]).

If you are first at the scene, ensure safety of the area. Consider conventional hazards (fire, smoke, fumes, electrical hazards, chemicals, explosives).

CAUTION

When responding to a known or suspected malicious act involving sealed sources, do not handle or otherwise come in contact with these sources. As long as the sources are intact there is no contamination hazard. Exposure hazards are diminished by avoiding close proximity to any sealed source.

In a case of nuclear weapon detonation, anticipate radiological as well as conventional hazards, which must be considered before any medical care can be offered.

Step 2
Wear protective equipment to include protective clothing, gloves, respiratory device, and boots as necessary. Wear personal dosimeters if available.

NOTE

Be aware of the emergency worker turn back guidance [5]. Be trained in advance on how to apply the guidance in an emergency. Radiation contamination hazards can be avoided by use of proper protective clothing and procedures.

NOTE

If you are the first on the scene and it is a mass casualty radiation emergency, notify the national health authority/agency responsible for the strategic and tactical medical management of the radiation emergency. The services need to be carefully coordinated to ensure both response to the emergency and the continued provision of effective health care services to the population not immediately affected by the emergency.

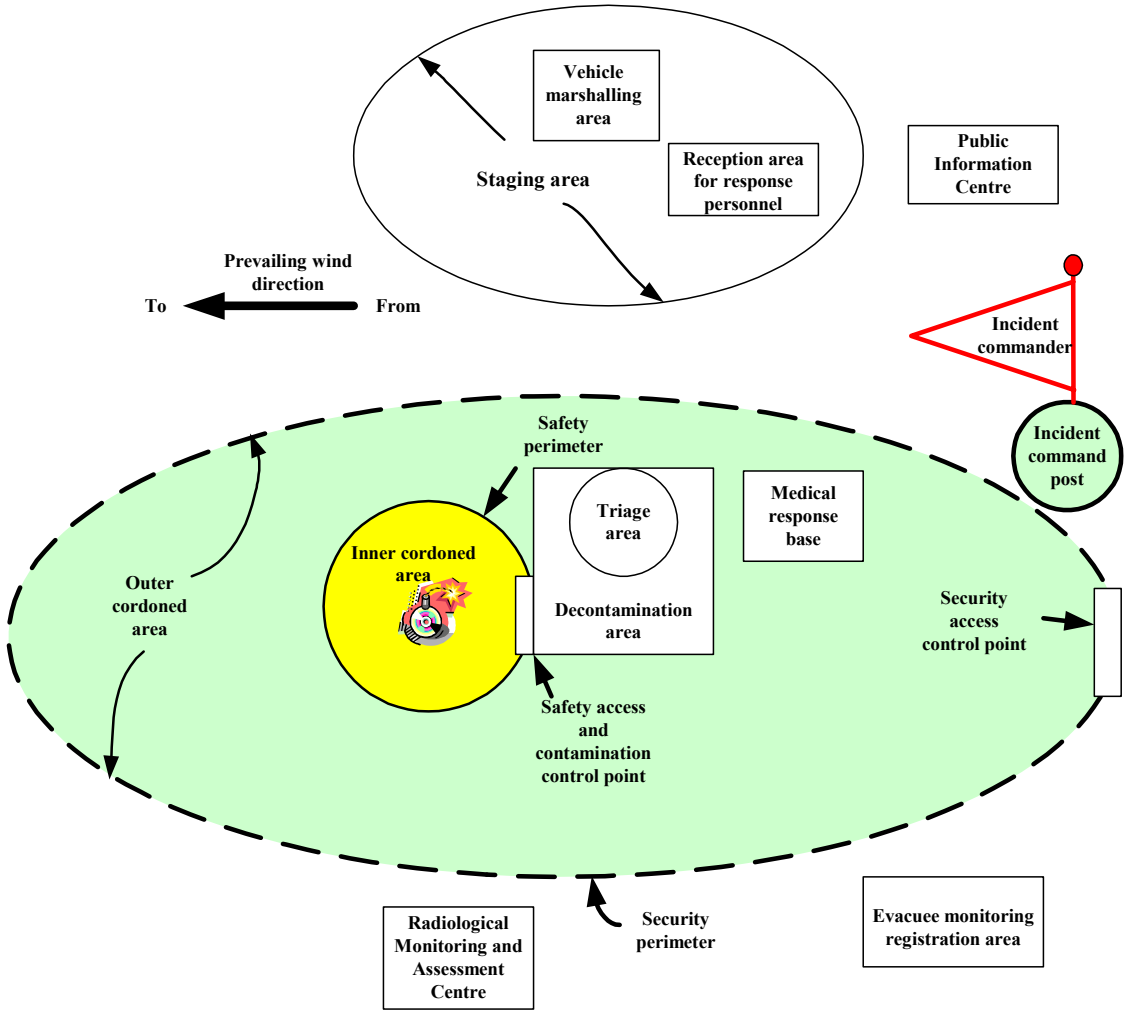


FIG. C1. Areas established by first resposnders [6]

Step 3

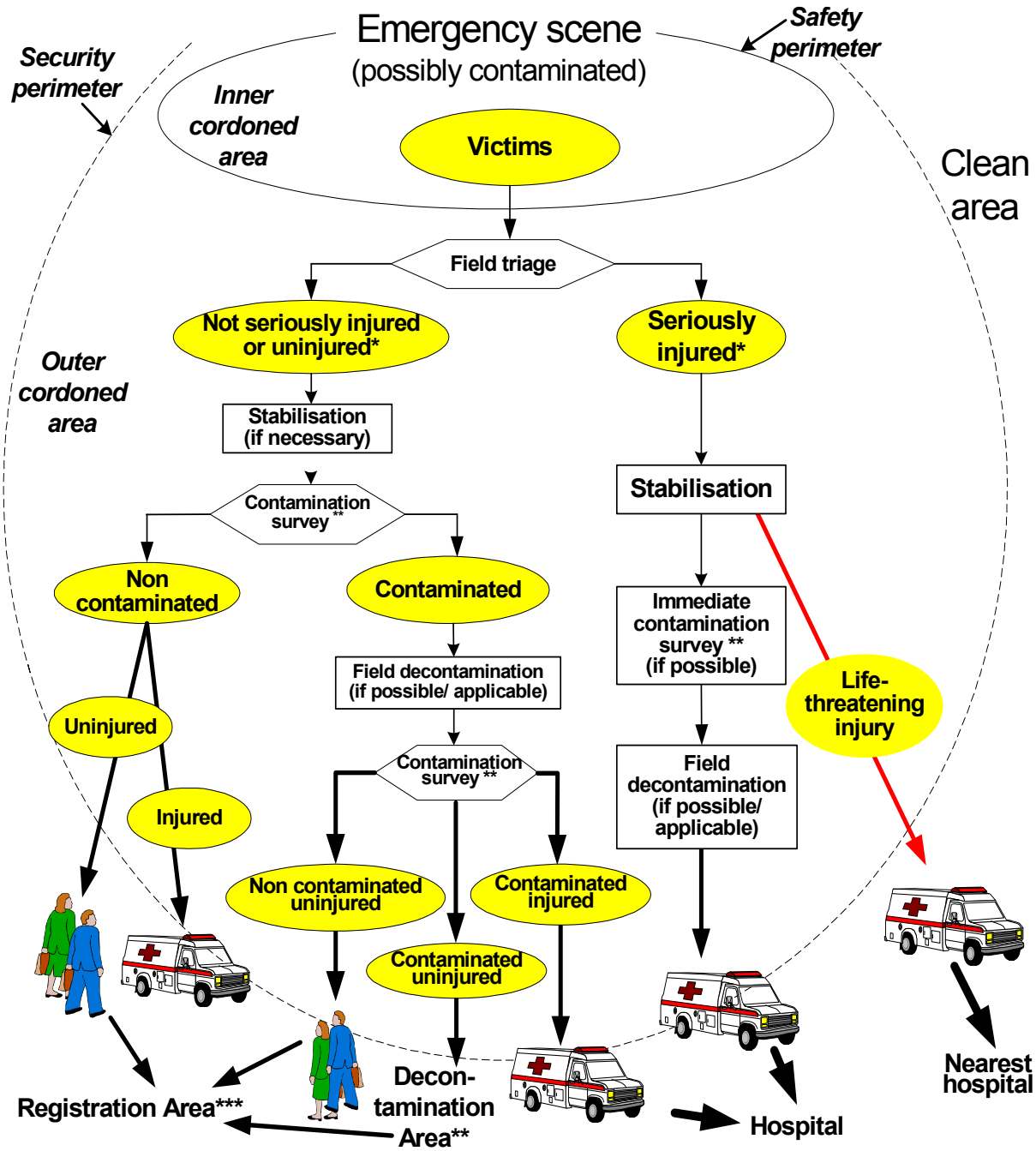
Perform search and rescue for injured persons as soon as possible. Remove injured persons from the hazard area into the triage area as soon as possible.

NOTE

The inner cordoned area within the safety perimeter could very often represent a direct hazard to victims and responders staying there long. Therefore, it is recommended to perform medical triage, radiological triage, and stabilization procedures in triage area outside the safety perimeter.

NOTE

Use Figure C2 as guidance for actions to perform.



* considered exposed if not proved otherwise.
** see Table D12 for criteria.
*** apply criteria from Table F2 if necessary.

FIG C2. Field triage during radiation emergency

Step 4

Assess the status of the victims using the national medical triage system to ensure that priority is given to the management of life-threatening injuries.

NOTE

Terminology of medical triage and methods to identify the different categories vary and are a matter of preference. To avoid confusion or delays in care, standard terminology and triage methods need to be established in the country. It should be stressed that serious medical problems always have priority over radiological concerns.

The triage categories (based on the **medical** conditions of the victims) used at the scene of the emergency could be as follows:

Priority 1: Casualties in need of immediate intervention;

Priority 2: Casualties in need of admission and early intervention;

Priority 3: Casualties who can wait for treatment;

OR

Immediate: Casualties in need of lifesaving measures performed without delay if they are to survive;

Delayed: Casualties who can wait for definitive treatment without causing additional harm;

Expectant: Casualties who will not survive or will require extensive resources and time if they are to be saved;

Minor: Casualties with slight injuries, who are generally ambulatory.

Step 5

Assess and treat life-threatening injuries immediately. Transport such patients into the hospital immediately, even if contamination survey has not been done. Stabilize other victims.

NOTE

Victim on backboard is handed across outer cordon line to Medical Transport Team. Do not delay transport of victim with life-threatening injury.

If necessary, request additional medical help.

NOTE

Move deceased casualties to a site that is not observed readily by the public or other casualties. Keep the deceased at this site until law enforcement officer(s) have acquired any available evidence and living casualties have been moved to the health care facility. A deceased person who has been externally exposed does not represent hazard to the responders. No special precautions are needed. Special precautions are needed only in case of internal or external contamination of the deceased person. In case the contamination is already discovered (using the usual methods of individual monitoring) appropriate radiation tag needs to be placed on the body (above the cover sheet with the purpose to be visible) before removing the contaminated body from the scene. On the scene of the emergency deceased casualties require basic preliminary decontamination before they are moved to the morgue or they are ready for release to designated place. Activities on the scene with regard to deceased casualties depend on the character of the radiation emergency and number of injured and/or deceased victims.

Step 6
Cover wounds with sterile dressings. Prepare injured persons for transport to the hospital.

Step 7
Initiate radiological survey of patients left on the scene (after those with life-threatening injuries have been already moved to the ambulance cars). Require assistance from Radiological Assessor. Perform radiological triage on the basis of radiological survey. Use the results of radiological survey and triage for appropriate medical and other actions.

NOTE

It is possible to perform radiological survey during stabilization of victim if monitoring procedures do not interfere with medical actions.

NOTE

Detailed description, criteria and guidance for radiological survey and triage are presented in the Procedure D7.

Step 8
Isolate contaminated non-critically injured victims. Remove all clothing found to be contaminated unless medically contraindicated. In cold environmental conditions, remove external contaminated clothing only just prior to transport. Use the following steps in removing the clothing:

- cut the clothing from head to toe and down the sleeves
- fold cut parts of the material back under itself as it is cut
- roll up the material.

By removing the clothing in such a way, it will be turned inside out. This will reduce the possibility of spreading contamination.

NOTE

See Appendix VIII for procedure of undressing contaminated victim.

Step 9
Ensure that Radiological Assessor has initiated evaluation of observable parameters for immediate dose assessment (see Table F3 for details). Use results of dose assessment provided by Radiological Assessor for selection of people requiring registration for long term follow-up.

Step 10
Isolate (bag and secure) clothing, shoes, and personal belongings.

NOTE

If malicious act is suspected, retain all items for forensic investigation.

Step 11
Make sure you have the records of radiological survey of the victims. Provide the records (Worksheet C1) to the Dosimetry Team in the hospital.

Step 12
Ask the police to obtain names and addresses of the involved persons for further interview(s) in accordance with Worksheet C2.

Step 13
Inform the receiving hospital about the nature of the conventional injuries and of any known or suspected exposure or contamination with radioactive materials. Identify the radioactive materials if known.

Step 14
Undergo personal and equipment contamination check performed by Radiological Assessor / Decontamination Team [4].

NOTE

When the medical conditions of victims do not require urgent hospitalization DO NOT leave the scene of an emergency without being checked for possible personal contamination. DO NOT take any equipment out of the scene area prior to being checked for possible contamination.
If you have to leave the scene urgently, contamination control procedures should be done as soon as reasonable.

NOTE

Under hazardous working conditions (heat, fire, fumes, etc.), there may be a need to medically check emergency responders for fitness (pulse, temperature, blood pressure, etc.) at pre- and post-entry to the emergency scene.

Step 15
Submit personal dosimeters to responsible person or organization (according to arrangements for keeping of dose records) for evaluation of personal doses.

Purpose
To provide guidance for transfer of victims from the emergency scene to the hospital emergency department.

Discussion
If possible, victims are to be transported by qualified medical or paramedical personnel who have not entered the controlled area on scene. Exposed victims require no special handling while contaminated victims are handled and transported using contamination control procedures. If there is any doubt, assume all victims are contaminated until proven otherwise. Continue medical assessment and treatment during transport when necessary.

Input
- Victims on site ready to be transported to the hospital emergency department.

Output
- Medical response actions during transportation of the victims;
- Delivery of victims to the ambulance reception area of the hospital.

Step 1
Upon arrival on scene wear personal dosimeters if available. Wear additional protective clothing if necessary and available, but always wear gloves.

NOTE

Members of the Medical Transport Team should not eat, drink, smoke or apply make-up at the emergency scene, in the ambulance vehicle, or at the hospital until they have been surveyed and released by the appropriate service of the hospital (Radiation Protection Support Group).

Step 2
Place the ambulance stretcher on the clean side of the outer cordoned line and unfold a clean sheet or blanket over it. Members of an Emergency Medical Response Team inside the cordoned area need to place the victims on a backboard and pass the victims across the outer cordoned line to the prepared stretcher of the Medical Transport Team. Do not remove the victim from the backboard.

Step 3
Cover victim by folding a sheet or blanket over him/her and securing it in place.

Step 4
Transport victims to the ambulance reception area of the hospital emergency department or alternative designated emergency hospital reception area for patients.

NOTE

In a mass casualty radiation emergency (usually as a result of malicious act), implement provisions to assess the concerns of members of the public (worried-well) about radiation exposure. Arrange to alert local medical facilities of the potential for arrival of concerned people if there is widespread pubic concern.

Step 5

Assess victims' vital status during transport and intervene appropriately. Check status of intravenous lines started in the controlled area.

Step 6

Advise the receiving hospital of any change in the victims' medical status. Ask for any special instructions the hospital may have.

Step 7

Use contamination control during transport. Change gloves as necessary.

Step 8

Follow the hospital's emergency response procedure upon arrival.

Step 9

Do not return to regular service (except for life saving transport) until you, the vehicle, and equipment have been monitored and decontaminated (if necessary) by the appropriate service of the hospital (Radiation Protection Support Group) or other qualified dosimetry service.

Step 10

Submit personal dosimeters to responsible person or organization (according to arrangements for keeping of dose records) for evaluation of personal doses.

SECTION D

RESPONSE AT THE HOSPITAL LEVEL

Caution: *The procedures in this section should be adapted to reflect national, local and hospital conditions and capabilities, including protocols of medical treatment for which they will be applied.*

Purpose

To provide guidance on establishing arrangements for contamination control in the hospital. The procedure does not describe medical care of victims.

Discussion

Following a radiation emergency, hospitals may admit emergency victims. When the hospital emergency department response team is notified that victims are arriving, it is essential that necessary emergency medical supplies and equipment are readily available. Delegation of duties to facilitate preparation for contamination control is recommended (see Fig.D1).

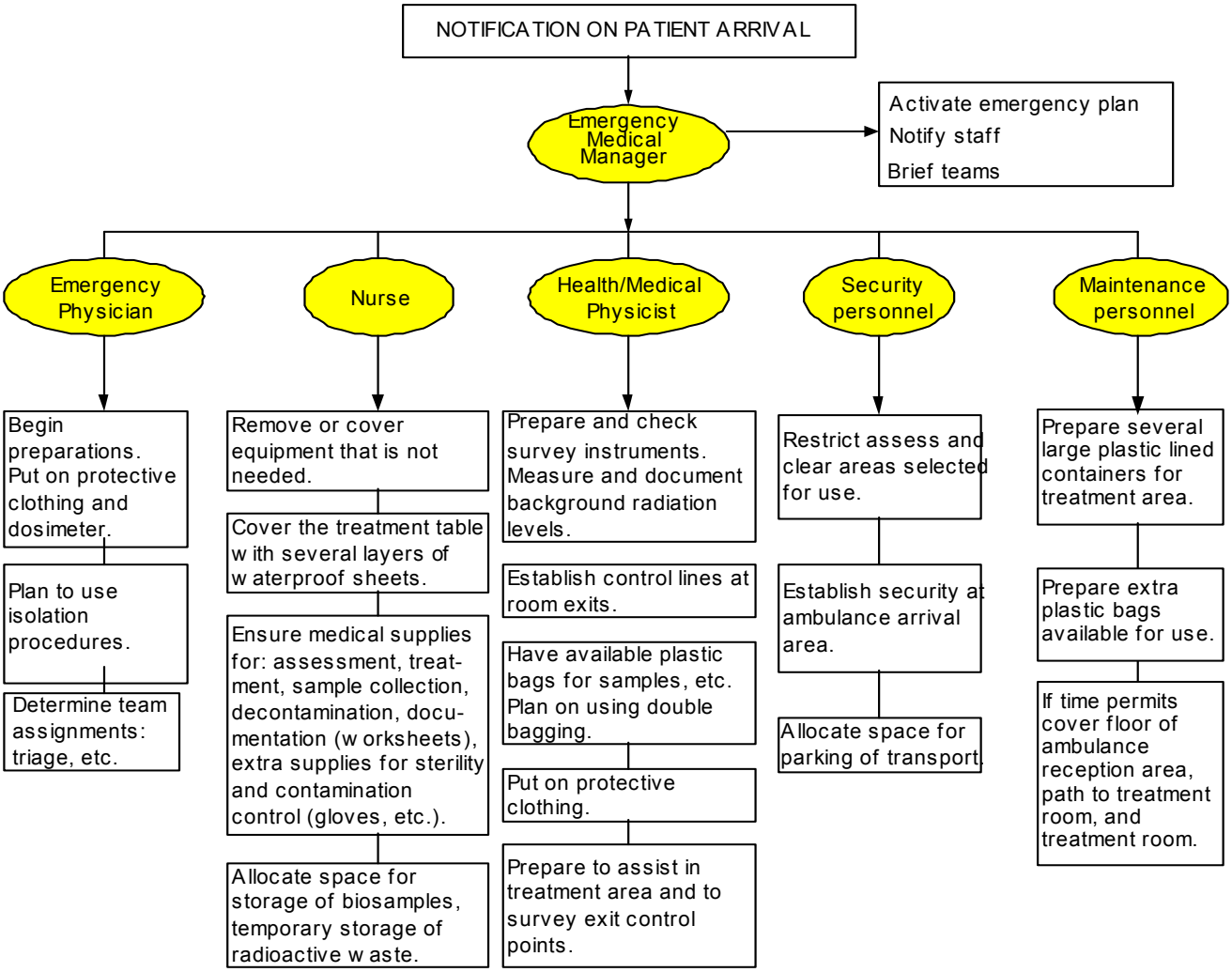


FIG. D1. Preparation for contamination control by Hospital Emergency Department Response Team

An ambulance reception area is to be established and clearly designated according to the hospital plan for medical response to radiation emergencies (examples of arranging the reception area are provided in Appendix IX).

NOTE

In mass casualty radiation emergencies, implement provisions to assess the concerns of members of the public (worried-well) about possible contamination. Be prepared to perform radiological triage of a large number of people at a location remote from the hospital (use athletic fields, stadiums, and community centres for this purpose).

Individuals who are only externally contaminated, but not injured, should be decontaminated at a facility other than the hospital to conserve hospital resources for the injured.

Input

- Notification about the arrival of victims.

Output

- Hospital prepared for admission of contaminated victims;
- Data on background radiation levels (Worksheet D1).

Prepare ambulance reception area

Step 1

Select the ambulance reception area close to the entrance of the treatment area.

NOTE

After a mass casualty event, hospitals need to 'lock down', providing only two entrances: to a site for triage of patients and to areas for personnel, staff, press, officials, etc.

Step 2

If time permits make a path from the ambulance entrance to the hospital entrance using rolls of wrapping paper or butcher paper about 1 m wide. Ordinary cloth sheets or square absorbent pads can be used if paper is unavailable. The floor covering should be taped securely to the floor. Rope off and mark the route to prevent unauthorized entry.

NOTE

Plastic sheets could be often slippery (especially, if wet). It needs to be remembered that placing floor covering should not delay urgent or emergent medical care.

NOTE

If the on-scene actions were performed properly, the ambulance stretcher, the ambulance, and the members of the Medical Transport Team most likely will not be contaminated. However, it needs to be assumed that they could be contaminated and the necessary precautions should be taken.

NOTE

Emergencies resulting from malicious acts involving radioactive material present different radiological contamination scenarios. For malicious acts involving sealed sources, victims of these events most likely will not be contaminated. However, they should be assumed contaminated until proven otherwise. For malicious acts involving radiological dispersal devices and nuclear weapons, victims and the members of the emergency services could be contaminated. Assume that all are contaminated and take necessary precautions.

Prepare hospital treatment area

Step 3
Select a treatment area near an outside entrance (if possible). Set up the area large enough to hold the anticipated number of victims. Clear the area of visitors and patients. Remove or cover equipment that will not be needed during emergency care of the victims.

Step 4
If time permits cover the floor of the treatment area in the same way as described in Step 2. The floor covering should be taped securely to the floor.

NOTE

Plastic sheets could be often slippery (especially, if wet). It needs to be remembered that placing floor covering should not delay urgent or emergent medical care.

Step 5
Take precautions to restrict access to the treatment area. Use strict isolation precautions, including protective clothing and double bagging. Use a buffer zone or secondary control line for added security.

Step 6
Check survey instruments and prepare them for use. Document background radiation levels in Worksheet D1. Make provisions to monitor anyone or anything leaving the area.

Step 7
Cover the treatment table with several layers of waterproof, disposable sheeting. Make sure that during the process of decontamination contaminated water will not pool under the patient.

Step 8
Prepare several large plastic-lined waste containers. Plastic bags of varying sizes should be available. Prepare warning labels and signs.

Step 9
Prepare the decontamination room of the treatment area. Establish a control line at the entrance to the decontamination room of the treatment area. Clearly mark with wide strip tape the floor at the entrance to the room to differentiate the controlled (contaminated) from the non-controlled (uncontaminated) side.

NOTE

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

Step 10
Use waterproof materials to limit the spread of contaminated liquids; e.g. waterproof dressings for wounds.

Step 11

Prepare enough instruments and supplies (e.g. outer gloves, dressings) to change when they become contaminated.

Prepare Emergency Department Response Team (each team member)

Step 12

Use universal precautions. Put on protective clothing (surgical clothing, including scrub suit, gown, mask, cap, eye protection, and gloves) in the following order.

1. Put on shoe covers.
2. Put on trousers. Tape trousers to shoe covers.
3. Put on surgical gown. Tie and tape gown openings.
4. Put on surgical cap and face mask.
5. Put on inner gloves. Seal gloves to gown sleeves by tape. Gloves should be under the arm cuff.
6. Put on splash protector.
7. Put on dosimeter.
8. Put on outer gloves (should be easily removable and replaced if they become contaminated).

NOTE

Fold-over tabs at the end of each taped area will aid removal.

NOTE

The purpose of protective clothing is to keep bare skin and personal clothing free of contaminants. This protective clothing is effective in stopping alpha and some beta particles but not gamma rays. Lead aprons, such as those used in the X ray department, are not recommended since they give a false sense of security - they will not stop most gamma rays. The member of the team using liquids for decontamination purposes should wear a waterproof apron.

NOTE

Shoe covers should be waterproof. For taping all open seams and cuffs, use masking or adhesive tape. Electronic personal dosimeter should be attached to the outside of the surgical gown at the neck where it can be easily removed and read. If available, a film badge or other type of dosimeter (TLD) can be worn under the surgical gown.

If radioactive contamination is discovered after patient has been admitted:

Step 13

Secure entire area where victim and attending staff have been. Do not allow anyone or anything to leave area until cleared by the Health/Medical Physicist.

Step 14

Establish control lines, and prevent the spread of contamination by checking anyone or anything before leaving the area.

Step 15
Perform all medical and other actions as required by the patient's status (as described in Procedures D1, and D5).

Step 16
Assess patient's radiological status using Procedure D7. Perform decontamination and or decorporation using Procedures D2, D3, and D4.

After handling the patient:

Step 17
Get checked for possible contamination. Remove contaminated clothing before exiting area in the following order:

1. Remove tape from gown, then from shoe covers.
2. Remove outer gloves.
3. Remove dosimeter.
4. Remove tape of inner gloves.
5. Take off gown avoiding shaking. Fold outer surface to avoid touching.
6. Lower trousers to below knee. Sit down on a chair placed at the clean side of the control line. Take off trousers.
7. Remove splash protector.
8. Take off surgical cap and face mask.
9. Take off shoe covers.
10. Take off inner gloves.

Get checked for possible contamination. If contaminated, take a shower and be resurveyed. Repeat the steps if necessary. If not contaminated, take a shower, dress in clean clothing before leaving area.

Step 18
Submit personal dosimeters to responsible person or organization (according to arrangements for keeping of dose records) for evaluation of personal doses.

Purpose

To provide guidance on the sequence of steps to be performed in the ambulance reception area upon arrival of casualties.

Discussion

Once the casualty arrives at the pre-planned reception area, the Emergency Physician or Triage Officer (qualified members of the Hospital Emergency Response Team) determines the general medical condition of the casualty and the severity of any associated injury. The Medical Transport Team or Emergency Medical Response Team should provide a report on the casualty's radiological status, including detected/suspected contamination, and any information regarding the nature of the emergency.

Input

- Reception of casualties;
- Data on casualties (Worksheet A2);
- Results of radiological survey of casualties on the scene (Worksheet C1).

Output

- Preparation of casualties for hospital admission;
- Results of radiological survey of casualties in the ambulance reception area (Worksheet D1);
- Medical information form (Worksheet D2).

Step 1

Meet the casualty at the ambulance reception area or at a triage area established near the treatment area.

NOTE

The medical team members dealing with the reception of casualties of a radiation emergency must be capable of carrying out a preliminary assessment, conducting a careful interview, if feasible, and performing triage and any necessary treatment of the victims of the radiation emergency.

NOTE

In suspected or known cases of radioactive contamination, wear protective clothing and follow radiation protection practices (see Procedure D0) to reduce the spread of contamination.

Step 2

Instruct members of the Medical Transport Team to stay with their vehicle until they, their vehicle, and equipment are surveyed and released by an appropriate service of the hospital (Radiation Protection Support Group).

Step 3

Perform triage of casualties. During triage, consideration should be directed first to medical, and then to radiological problems.

NOTE

Triage must occur at each stage (on-scene, reception, emergency department) due to changes in casualty's status. The purpose of triage at the hospital is to sort the injured by priority and determine the best use of available resources (e.g. personnel, equipment, medication, hospital beds).

NOTE

Serious medical problems always have priority over radiological concerns, and immediate attention is directed to life-threatening problems. Radiation injury rarely causes unconsciousness or immediate visible signs of injury and is not immediately life threatening; therefore other causes of injury or illness must be considered.

Act in accordance with the results of triage:

Condition of casualty	Perform action
Life-threatening	stabilize; move to intensive care department; do not perform radiological survey if it interferes with stabilization.
Stable	proceed with steps described below

NOTE

If patient is not injured but suspected of having been exposed to radiation exposure above minimum dose criteria established for long term medical follow-up (on the basis of immediate dose assessment performed by Radiological Assessor), request Health/Medical Physicist for confirmation of the results of dose assessment. If confirmed, ensure registration for long term medical follow-up (see Procedure G2 for details).

Step 4

If the casualty's clothing was not removed before arrival at the hospital (at the emergency scene), remove the clothing as promptly as possible, unless medically contraindicated, taking care to avoid spread of contaminants embedded in or on the clothing.

NOTE

See Appendix VIII for procedure of undressing contaminated casualty.

NOTE

Clothing and any accompanying sheets and blankets should be placed in plastic bags, sealed, labelled, and properly stored for radiological analysis.

Step 5

If the patient's condition allows, ask Health/Medical Physicist or Dosimetry Team to perform an initial, brief radiological survey of the patient(s) to determine if they are contaminated and to estimate levels of contamination on specific body areas.

NOTE
Survey should be done under supervision of medical specialists, using the Procedure D7 and completing Worksheet D1.

NOTE
Note the possibility that casualty could have cardiostimulator with the radioactive element used as a power supply.

Step 6
Use the following procedures to assess and treat casualties on the basis of survey results:

Patients	Procedure
Contaminated	D1a
Non-contaminated	D1b

Step 7
Transfer patients in accordance with their condition:

Patient condition	Transfer to:	Notes
contaminated and exposed	hospital treatment /decontamination area in the emergency department	Do not transfer to decontamination area if medically contraindicated. Use clean hospital stretcher to transfer.
non-contaminated and exposed	regular patient treatment area in the emergency department	
conventional trauma		
contaminated and non-injured	remains in a controlled area	Remains until appropriate personnel can assist in a complete radiological assessment and decontamination is accomplished.

Step 8
Record information obtained in the ambulance reception area from the Medical Information Form (Worksheet D2).

NOTE
Recording information should not interfere with medical care, and will be continued in the treatment area.

Purpose

To provide guidance for assessment and treatment of contaminated/exposed/injured people in treatment area.

Discussion

Contaminated patients are admitted to a specially prepared part of the treatment area. When in doubt, a critically injured patient should be taken immediately into the specially prepared area or transferred to the care of an appropriate specialist.

Contaminated patients can have radioactive material deposited on skin surfaces, in wounds, or internally (ingested, inhaled, or absorbed).

If the patient(s) have internal contamination only, then they don't present a direct hazard to others, unless the internal contamination is extremely large. In that case, medical personnel and other people around (patients, relatives) may be subject to external exposure as a result of internal contamination of the patient. However, such exposure usually is low.

If the patient(s) have external contamination of the skin, clothing and/or contaminated excreta, then they present hazard in spreading contamination and special precautions need to be implemented to prevent the spread of contamination.

Input

- Results of radiological survey of the casualty in the ambulance reception area (Worksheet D1);
- Medical Information Form (Worksheet D2).

Output

- Samples for medical and radiological analysis;
- Medical Information Form (Worksheet D2);
- Results of radiological survey of casualties in the treatment area (Worksheet D1).

Step 1

Reassess the patient's airway, breathing, and circulation prior to attention to his/her radiological status. Promptly assess level of consciousness and vital signs and stabilize the patient's condition.

NOTE

In suspected or known cases of radioactive contamination, wear protective clothing and follow radiation protection practices (see Procedures D0) to reduce the spread of contamination.

NOTE

The contaminated patient admitted with an airway or endotracheal tube must be considered internally contaminated.

Step 2

Remove clothing as promptly as possible without compromising life or limb (if the clothing was not removed at the scene of the emergency or in the ambulance reception area).

NOTE

See Appendix VIII for procedure of undressing contaminated casualty.

CAUTION

Take care to avoid spread of any contaminants embedded in or on patient's clothing.

Step 3

Place clothing, and any accompanying sheets, blankets, etc. in a plastic bag. Label the bags with warning signs and patient's identification information. Store the bags in a secure place away from the immediate work area.

NOTE

In cases of external exposure, collect, label and store for future dose reconstruction (neutron activation analysis) the following items: watch, buttons, and dental crowns.

Step 4

Change gloves after handling clothing or other potentially contaminated items.

Step 5

Ask the Health/Medical Physicist or Dosimetry Team to perform radiological survey.

NOTE

Survey should be done under supervision of medical specialists, using Procedure D7 and completing Worksheet D1.

Step 6

Obtain complete and detailed medical and occupational history. Examine the patient.

NOTE

The patient should be questioned about allergies, currently used medication, any history of chronic or recent illness, and recent nuclear medicine tests**.** The patient's level of anxiety should be noted, and psychological support offered.

CAUTION

If a woman is pregnant, request Health/Medical Physicist to perform dose assessment in order to inform her about possible risk to the child. Use international guidance for giving advice [11].

Step 7

Obtain a complete emergency history to determine the possibility of exposure to radiation from external sources. If history is incomplete, observe for radiation induced signs or symptoms described in Steps 9, 10 and 11. Request Health/Medical Physicist to perform dose assessment.

Step 8

Assess possibility of internal contamination. If suspected, initiate collection of samples for analysis (see Table D2, Procedures F6 and F7 for details). Request Health/Medical Physicist to perform assessment of internal dose. Initiate decorporation treatment if necessary (see Procedure D3 for details).

Step 9

Observe patients with nausea and vomiting in the emergency department for about six hours. Manage patients in accordance with guidance given in Table D1 [2].

NOTE

Most patients exposed to acute whole body (or large body volume) doses of penetrating, photon radiation of about 1.0 Gy will experience radiation induced nausea/vomiting, the onset and severity of which is dose and dose-rate dependent.

TABLE D1. MANAGEMENT OF RADIATION INJURIES FROM WHOLE BODY EXPOSURE BASED ON TIME TO VOMITING

Whole body exposure		**Decision**
Clinical signs	**Absorbed dose, Gy**	
No vomiting	< 1	Outpatient with 5 weeks surveillance period (blood, skin)
Vomiting 2-3 h after exposure	1-2	Surveillance in a general hospital (or outpatient for 3 weeks followed by hospitalization if necessary)
Vomiting 1-2 h after exposure	2-4	Hospitalization in a haematological or surgical (burns) department
Vomiting earlier than 1 h after exposure (and/or other severe symptoms, e.g. hypotension)	> 4	Hospitalization in a well equipped haematological or surgical department OR transfer to a specialized centre for radiopathology

Step 10

Determine the possibility of local radiation injury (LRI). If you suspect LRI, photographs of the affected area(s) should be obtained twice weekly and then daily if signs of radiation injury become evident. Photographs should be added to the patient's medical history records (Worksheet D2).

NOTE

Malicious acts involving the spread of sealed sources can result in many persons with LRI in various stages of development depending upon when the event is discovered. Only those victims who have been in direct contact with a sealed source will exhibit signs and symptoms of radiation injury. If a malicious act involving sealed sources has not been discovered, one should be suspicious if a number of persons present with localized erythema, blisters, or

necrotic lesions of unknown origin. In this case, ask if any small metallic objects were found and handled in the recent past.

Malicious acts involving radiological dispersal devices are unlikely to produce LRI.

LRI from nuclear weapons may present as the result of fallout some distance away from an emergency. Fallout on the skin for several hours may cause skin changes. A radiological survey of such victims should be performed. Decontamination may be performed simply by having the victims shower and change clothing.

NOTE

See Procedure D5 for details of LRI management.

Step 11

Take necessary laboratory samples using guidance in Table D2.

TABLE D2. IMPORTANT LABORATORY SAMPLES TO BE TAKEN IN TREATMENT AREA FOR SUBSEQUENT ANALYSIS

Samples Needed	Purpose	Description
***In all cases of radiation injury*:**		
Immediate CBC and differential (follow with absolute lymphocyte counts every 6 h for 48 h when history indicates possibility of whole body irradiation)	To assess the exposure dose range; initial counts establish a baseline, subsequent counts reflect the degree of injury	Choose a non-contaminated area for venapuncture; cover puncture site after collection
Routine analysis of urine	To determine if kidneys are functioning normally and establish a baseline of urinary constituents; especially important if internal contamination is a possibility	Avoid contaminating specimen during collection; if necessary, give the patient plastic gloves to wear for collection of specimen; label specimen "Number 1," with date and time
***When external contamination is suspected*:**		
Swabs from body orifices	To assess possibility of internal contamination	Use separate saline- or water-moistened swabs to wipe the inner aspect of each nostril, each ear, mouth, etc.
Wound dressing, swabs from wounds	To determine if wounds are contaminated	Save dressings in a plastic bag. Use moist or dry swabs to sample secretions from each wound, or collect a few drops of secretion from each using a dropper or syringe; for wounds with visible debris, use applicator or long tweezers or forceps to transfer samples to specimen containers which are placed in lead storage containers (pigs)
***When internal contamination is suspected*:**		
Urine: daily excretion for the period of time depending on contaminant and activity in the body	Body excreta may contain radionuclides if internal contamination has occurred	Use 24-hour urine collection container
Faeces: daily excretion for the period of time depending on contaminant and activity in t body		

NOTE

The absolute lymphocyte content is of special informative importance (specially for patients with nausea and vomiting) and should be obtained every 6 hours for at least 2 days and then every 12 hours for an additional 5 days. The absolute lymphocyte content could be used as effective criteria for survival prognosis (Table D3).

TABLE D3. ABSOLUTE LYMPHOCYTE CONTENT IN FIRST TWO DAYS AFTER RADIATION EXPOSURE AND SURVIVAL PROGNOSIS

Absolute lymphocyte content	Severity grade of ARS	Survival prognosis
700-1000	Mild	Definitely
400-700	Moderate	Probable
100-400	Severe	Possible with the special treatment
<100	Very severe	Problematic

NOTE

All samples ***must*** be placed in separate, labelled containers that specify name, date, time of sampling, area of samples, and size of area sampled. It is suggested that blood, urine, faeces, or other samples taken in the emergency treatment period be retained for subsequent investigation. Appropriate advice (legal, radiation safety, etc.) needs to be obtained regarding the storage and disposition requirements of collected samples.

NOTE

In a mass casualty event, hundreds to thousands of people may attempt to come to a hospital, putting the hospital in the position where it cannot possibly take a blood count on every one of them. Anyone who has or might exhibit prodromal effects would need to be considered for CBC with differential. This is best repeated every 6 hours for at least 2 days.

NOTE

All samples taken from individuals involved in a known or suspected malicious acts involving radioactive material must be retained as evidence for forensic examination.

Step 12

Complete Medical information form (Worksheet D2).

NOTE

Recording the information should not interfere with medical care. Data should be added in the Medical Information Form started in the ambulance reception area.

Step 13

Identify the appropriate Medical Service within the hospital or Referral Hospital for continuing medical management of the patients. Make arrangements to transfer patients with known or suspected significant whole body or local radiation injury to medical specialists of appropriate Medical Service or to Referral Hospital for continuing care.

Performed by: *Hospital Emergency Department Response Team*	**PROCEDURE D1b** **ASSESSMENT AND TREATMENT OF NON-CONTAMINATED /EXPOSED/INJURED PEOPLE IN TREATMENT AREA**	*Page 1 of 3*

Purpose
To provide guidance for assessment and treatment of non-contaminated/exposed/injured people to be performed in the hospital treatment area.

Discussion
Non-contaminated victims are admitted to the standard hospital emergency treatment area. Absence of contamination means that no special procedures to prevent the spread of contamination should be undertaken at this stage. If the patient has been exposed only to external sources of radiation, there is no radiation threat to medical personnel and others around (patients, relatives).

Input
- Results of radiological survey of the casualties in the ambulance reception area (Worksheet D1);
- Medical Information Form (Worksheet D2).

Output
- Samples for medical and radiological analysis;
- Medical Information Form (Worksheet D2);
- Results of radiological survey of the patients in the treatment area (Worksheet D1).

Step 1
Reassess the patient's airway, breathing, and circulation. Promptly assess the level of consciousness and vital signs of the patient and stabilize the patient's condition.

Step 2
If necessary, ask the Health/Medical Physicist or Dosimetry Team to perform a radiological survey to confirm non-contaminated status of each patient (with special attention to internal contamination).

Step 3
Obtain complete and detailed medical and occupational history. Examine the patient.

NOTE

The patient should be questioned about allergies, currently used medication, any history of chronic or recent illness, and recent nuclear medicine tests**.** The patient's level of anxiety should be noted, and psychological support offered.

CAUTION

If a woman is pregnant, request Health/Medical Physicist to perform dose assessment in order to inform her about possible risk to the child. Use international guidance for giving advice [11].

Step 4

Stabilize patients with conventional injury or illness. Obtain a complete history to determine the possibility of exposure to radiation from external sources. Following stabilization of non-exposed patients discharge or assign these patients to care by medical specialists of appropriate services or transfer to Referral Hospitals as necessary. If history is incomplete, observe for radiation induced signs or symptoms described in Steps 5, 6, and 7.

Step 5

Observe patients with nausea and vomiting in the emergency department for about six hours. Manage patients in accordance with guidance given in Table D1 [2].

NOTE

Most patients who have been exposed to acute whole body (or large body volume) doses of penetrating, photon radiation of about 1.0 Gy will experience radiation induced nausea/vomiting, the onset and severity of which is dose and dose-rate dependent.

Step 6

Determine the possibility of local radiation injury (LRI). If you suspect LRI, photographs of the affected areas should be obtained twice weekly and then daily if signs of radiation injury become evident. Photographs should be added to the medical history records of the patient (Worksheet D2).

NOTE

Radiation injury of skin produces lesions similar to the thermal burns. Clinical changes in LRI (hands, feet, thighs, etc.) develop slowly over time (several days to many weeks). In most cases, signs and symptoms of LRI will be seen and treated in the appropriate service of the hospital or in the Referral Hospital (see Procedure D5).

Step 7

Take necessary laboratory samples using guidance in Table D2.

NOTE

The absolute lymphocyte content is of special importance and should be obtained every 6 hours for at least 2 days and then every 12 hours for an additional 5 days. The absolute lymphocyte content could be used as effective criteria for survival prognosis (Table D3).

NOTE

All samples ***must*** be placed in separate, labelled containers that specify name, date, time of sampling, area of samples, and size of area sampled. It is suggested that blood, urine, faeces, or other samples taken in the emergency treatment period be retained for subsequent investigation. Appropriate advice (legal, radiation safety, etc.) needs to be obtained regarding the storage and disposition requirements of collected samples.

NOTE

All samples taken from individuals involved in a known or suspected malicious act involving radioactive material must be retained as evidence for forensic examination.

Step 8

Complete Medical Information Form (Worksheet D2).

NOTE

Recording the information should not interfere with medical care. Data should be added to the Medical Information Form started in the ambulance reception area.

Step 9

Identify the appropriate medical service within the hospital or Referral Hospital for continuing medical management of the patient(s). Make arrangements to transfer patients with known or suspected significant total body or local radiation injury to medical specialists of appropriate medical service or to Referral Hospital for continuing care.

Purpose
To provide guidance for decontamination of people in the treatment area.

Discussion
Good judgement is essential in determining decontamination priorities. Since some radioactive material is corrosive or toxic because of its chemical properties, medical attention might have to be directed first to a non-radiological problem if radioactive material is a component of acid, fluoride (uranium hexafluoride-UF_6), mercury, lead, or other compounds.
The purpose of decontamination is to prevent or reduce incorporation of the material (internal contamination), to reduce the radiation dose from the contaminated site to the rest of the body, to contain the contamination, and to prevent its spread.

Input
- Results of radiological survey of patients (Worksheet D1).

Output
- Patient(s) after completed decontamination procedure;
- Data on decontamination efficiency (Worksheet D3).

Step 1
Review information from Worksheet D1 and determine decontamination method to use.

NOTE
Wear protective clothing and follow radiation protection practices (see Procedure D0) to avoid the spread of radioactive contamination.

Step 2
Explain to the patient the actions you are going to perform.

Step 3
Perform decontamination of the patient in accordance with the results of radiological survey, using the steps below.

NOTE
Decontamination should be performed with the following priorities: wounds, orifices, high-level skin areas, low-level skin areas.

NOTE
Patient's vital status should be assessed on a regular basis during decontamination process.

Step 4
Document your actions and efficiency of decontamination in Worksheet D3.

NOTE

It may be necessary that the waste water from the decontamination procedure be retained and analysed before being discharged. However, this recommendation is not mandatory. Furthermore, the installation of an elaborate holding system is not likely to be justified because of the infrequency of the event.

Any radiation hazard to the general public will be virtually eliminated when the inherently small and infrequent volume of radioactive waste is mixed with and diluted by other sewage effluents of the hospital. However, if local protocol requires, local health authorities should be notified.

Decontamination of wounds

Step 5

Drape contaminated wound with a waterproof material to limit the spread of radioactivity.

NOTE

In a contamination emergency, any wound must be considered contaminated until proven otherwise and should be decontaminated prior to decontaminating intact skin. When wounds are contaminated, the physician must assume that uptake (internal contamination) has occurred. Appropriate action is based on half-life, solubility, radiotoxicity, and the amount of radioactive material. It is important to initiate measures that prevent or minimize uptake of the radioactive material into body cells or tissues.

Step 6

Decontaminate the wound by gently but thoroughly irrigating with saline solution or water. More than one irrigation is usually necessary. Monitor wound after each irrigation. Remove contaminated drapes, dressing, etc. before each monitoring for accurate results. Change gloves frequently.

NOTE

When monitoring contaminated wounds or irrigation fluids, γ-radiation is easily detected while β-radiation may prove more difficult to detect. Without special, highly sophisticated wound probes, α-contamination will not be detected.

Step 7

Treat wound after repeated irrigation like any other wound. If the preceding decontamination procedures are not successful, and the contamination level is still seriously high, consider conventional debridement of the wound.

NOTE

Excision of vital tissue should not be initiated until expert medical or health physics advice is obtained. Debrided or excised tissue should be retained for dose assessment.

Step 8

Remove embedded radioactive particles, if visible, with forceps. Save for analysis.

NOTE

Puncture wounds containing radioactive particles, especially in the fingers, can be decontaminated by using an "en bloc" full thickness skin biopsy with a punch biopsy instrument.

Step 9

After decontamination of the wound, cover it with a waterproof dressing.

Step 10

Decontaminate the area around the wound as thoroughly as possible before suturing or other treatment.

NOTE

Contaminated burns (chemical, thermal) are treated as any other burns. Contaminants can slough off with the burn eschar. Dressing and bed linens can become contaminated and should be handled appropriately.

Decontamination of body orifices

Step 11

Decontaminate eyes, ears, and mouth, using guidance in Table D4.

TABLE D4. GUIDE FOR DECONTAMINATION OF BODY ORIFICES

Contamination area	Method	Technique	Remarks
Eyes	Flushing with water or saline solution	Roll back eyelid. Rinse the eye by directing the stream of water from the inner canthus to the outer canthus of the eye while avoiding contamination of the nasolacrimal duct.	Should be done by trained personnel.
Ears	Flushing	Rinse external part of the ear. Clean the opening of the ear channel with the cotton swabs. Use ear syringe to rinse the auditory canal.	Be cautious not to damage tympanic membrane.
Mouth	Flushing	Encourage the victim to brush the teeth with toothpaste and frequent rinsing of the mouth.	If the pharyngeal region is also contaminated, advise victim to gargle with a 3% hydrogen peroxide solution. Warn the patient not to swallow. If radioactive materials were swallowed, apply gastric lavage.

Step 12

If there is a suspicion of inhalation, a nose blow needs to be encouraged and the tissue saved for a radiological analysis.

NOTE

Contaminated body orifices, such as the mouth, nose, eyes and ears need special attention because absorption of radioactive material is likely to be much more rapid in these areas than through the skin.

Decontamination of hair

Step 13

Decontaminate hair, using the guidance in Table D5.

TABLE D5. GUIDE FOR DECONTAMINATION OF HAIR

Contamination	Method	Technique	Remarks
Mild	Washing with shampoo and water	Use light pressure with heavy lather. Wash for 2 minutes 3 times. Rinse. Monitor.	When shampooing the head, avoid getting any fluids into the mouth, nose, ears or eyes.
Resistant	Washing with soap, soft brush and water	Make soap into a paste. Use additional water and a mild scrubbing action.	When shampooing the head, avoid getting any fluids into the mouth, nose, ears or eyes. Do not erode the skin.
Non removable	Haircutting	Cut the hair.	Do not shave since small nicks or abrasions can lead to internal contamination.

Decontamination of intact skin – localized areas

NOTE

Begin decontamination with the least aggressive method and progress to more aggressive ones. Whatever the procedure, take care to limit mechanical or chemical irritation of the skin. All cleaning actions are to be performed from periphery of contaminated area towards the centre.

Step 14

Wash the contaminated area gently under a stream of warm water (do not splash).

NOTE

Use warm, never hot water. Cold water tends to close the pores, trapping radioactive, material within them. Hot water causes vasodilatation with increased area blood flow, opens the pores, and enhances the chance of absorption of the radioactive material through the skin.

Step 15

If washing with plain water is ineffective, use a mild soap (neutral pH) or surgical scrub soap. Scrub area for 3–4 minutes. Avoid aggressive rubbing which tends to cause abrasion and erythema. Rinse 2–3 times and blot dry. Check contaminated area with radiation monitor. Repeat steps (including monitoring between each scrubbing and rinsing), if necessary.

NOTE

Sodium hypochlorite, diluted 1 to 10 with water, is an effective decontamination agent. A mildly abrasive soap (or a 1 to 1 mixture of powdered detergent and cornmeal mixed with water into a paste) can be used for calloused areas.

Step 16

Stop decontamination when the radiation level cannot be further reduced or if skin irritation is evident.

NOTE

Complete decontamination, which returns the area to a background survey reading, is not always possible because some radioactive material can remain fixed on the skin surface. Decontamination should be only as thorough as practical. For resistant contamination cover the area with cotton compress and a thin plastic cover (for hands use a cotton glove covered by a plastic or rubber glove). Wait 1–2 hours for sweating. Remove covers and re–clean area. Survey. Repeat procedure if necessary.

Decontamination in cases of extensive contamination

Step 17

Decontaminate using sink, basin or shower depending on the area of contamination. Caution the patient to avoid splashing water into the eyes, nose, mouth, or ears. Repeat washing, if necessary. Provide clean towels for drying after each wash. If necessary, the water may be discharged into the sewer.

Transfer patient from decontamination room of treatment area

Step 18

Once emergency treatment and decontamination is completed and final survey reveals no transferable contamination, the patient is ready for transfer. Use the guidance in Table D6 to transfer the patient out of a decontamination room of treatment area.

TABLE D6. TRANSFER METHODS IN RESPECT OF THE PATIENT'S CONDITION

Category of patients	Actions
Ambulatory	1 Place a clean floor covering on the floor. 2 Move patient to control line. 3 Patient (with shoe covers on) can either walk out or get into a wheel chair on the clean side of the control line.
Non-ambulatory 1st Method	1. Use a clean floor covering to make path to exit control point. 2. Bring clean stretcher in on path. 3. Transfer patient to clean stretcher.
Non-ambulatory 2nd Method (if control exit is a wide opening)	1 Move treatment table to control line. 2 Transfer patient across control line to clean team.

CAUTION

Everyone transferring the patient should be wearing clean gloves.

Step 19

Record all actions and facts in your logbook and Worksheet D3.

Purpose

To provide guidance for decorporation of people in the treatment area.

Discussion

Patients with a significant amount of internal contamination should be treated in order to reduce the radiation dose from absorbed radionuclides and thus the risk of long term radiation effects. There are several approaches for minimizing internal contamination. The first is focused on reducing the absorption of radionuclides and their deposition in target organs. The second approach aims to increase the excretion of the radionuclides from the body.

Treatment procedures are most effective if initiated as soon as possible after contamination has occurred. Hence, in practice, the critical initial treatment decision has to be based on the emergency history, rather than dose estimates. When deciding on decorporation, comparison is to be made between the benefit of removing the radioactive contaminants using modalities associated with significant side effects and the short and long term health effects of contamination without treatment. Additional treatment should be based on more detailed reports of *in-vivo* measurements and bioassay. Special consideration is necessary when the estimated intake or dose significantly (e.g. 10 times) exceeds the annual limits.

Input

- Results of radiological survey of the patients (Worksheet D1);
- Information for internal dose assessment (Worksheet F6);
- Results of *in-vitro* and *in-vivo* bioassay measurements (Worksheets F9, F11);
- Medical information on patients (Worksheet D2);
- Data on efficiency of decorporation for decision on continuation of treatment (Worksheet D4).

Output

- Patient(s) after completed decorporation procedure.

NOTE

Decorporation treatment should be performed under the direction of a physician and include specific patient medical information and conditions.

Step 1

Review information from Worksheets D1, D2, F6, F9, F11 regarding exposure conditions, radionuclide(s) involved, and results of measurements (if available) and determine decorporation method to use.

Step 2

Explain to the patient the actions you are going to perform.

Step 3

Perform immediate decorporation treatment, if there is a large ingestion with an unknown radionuclide, until the radionuclide specific decorporation treatment is possible.

NOTE

Immediate treatment methods could include reduction of absorption (administration of emetics, antacids, charcoal, laxatives, and gastric lavage in case of ingestion). Usually, gastric lavage should be done until washings are free of radioactive material (no more than two times background radiation or repeated lavage does not result in further reduction of contamination). This is only effective if done within 1–2 hours after ingestion and should only be used for large single intakes of radioactive material.

CAUTION

Pulmonary lavage is to be considered only in extreme circumstances after inhalation of very large amounts of insoluble compounds of insoluble radionuclides that would be likely to result in major pulmonary compromise if not removed.

Step 4

Perform radionuclide specific decorporation treatment of the patient in accordance with the results of bioassay analysis and whole body counting, using Table D7.

NOTE

Patient vital status should be assessed on a regular basis during decorporation process.

Step 5

Document your actions in the Medical Information Form (Worksheet D2).

Step 6

Request Bioassay Team to evaluate and report data on efficiency of decorporation treatment, already performed. Make decision on continuation of decorporation treatment.

Step 7

Continue decorporation procedures until not necessary.

Step 8

Complete Medical Information Form (Worksheet D2).

TABLE D7. GUIDE FOR RADIONUCLIDE SPECIFIC DECORPORATION TREATMENT

Radionuclide	Decorporation treatment	Caution	Note
Americium (Am) Californium (Cf) Curium (Cm) Neptunium (Np) Plutonium (Pu) Ruthenium (Ru) Thorium (Th) Iron (Fe) Cobalt (Co) Zirconium (Zr)	**Substance:** Ca-DTPA (trisodium calcium diethylenetriaminepentaacetate). **Administration:** 1 g Ca-DTPA by the most appropriate route **Medication route:** *Intravenous infusion:* Undiluted solution over a period of 3-4 minutes, or diluted solution in 100-250 ml normal saline or 5% glucose. *Inhalation in a nebulizer:* 30 minutes inhalation of an aerosol made from a 5 ml ampoule of 20% concentrated solution (or 4 ml of 25% concentrated solution).	Blood pressure should be monitored during drug infusion. Ca-DTPA is contraindicated in cases of nephritic syndrome or bone marrow depression. Zn-DTPA should be used if available to treat a pregnant female. DTPA should not be used in cases of massive uranium contamination because of the risk of acute nephritis due to uranium precipitation in the kidneys.	Zn-DTPA may be used if Ca-DTPA is not available. However, Ca-DTPA is approximately 10 times more effective during the first 24 hours. DTPA can reduce dose by about 80% if given within less than 4 hours after intake of soluble compounds, but less than 25% efficient after intake of insoluble compounds.
Caesium (Cs)	**Substance:** Prussian Blue (ferric hexacyanoferrate). **Administration:** 1 g Prussian Blue 3 times daily. For children: 1-1.5 g daily in 2-3 divided doses. Continue for several days. **Medication route:** *Oral administration:* The capsules are to be swallowed whole with some liquid or dispersed in warm water and drunk as a solution.	Essentially no contraindications. Is effective only if gastrointestinal motility is intact. Patients will experience blue-tinged stool and should be so informed.	Prussian blue reduces the dose by a factor of about 2-3. May be given in pregnancy if clinically indicated. Prussian Blue is supplied from HEYL GmbH in Germany as a 0.5 g capsule (Radiogardase®-Cs). Prussian Blue is also commonly called Berlin Blue or ferric ferrocyanide.
Cobalt (Co)	**Substance:** Co-EDTA (cobalt ethylenediaminetetraacetate). **Administration:** 0.6 g Co-EDTA (2 ampoules of 300 mg/20 ml). **Medication route:** *Intravenous infusion:* Slowly inject 40 ml of the Co-EDTA solution followed immediately by 50 ml of hypertonic glucose solution.	Blood pressure should be monitored during drug infusion.	Co-EDTA is supplied from Serb Labs (Kelocyanor®). Ca-DTPA may be used if Co-EDTA is not available.
	Substance: Cobalt gluconate. **Administration:** 0.9 mg Co-gluconate (2 ampoules of 0.45 mg / 2 ml). **Medication route:** *Sublingual administration:* Do not dilute the solution.		Co-gluconate is supplied from Labcatal Labs (Cobalt Oligosol®).
Iron (Fe)	**Substance:** Deferoxamine (Desferal®, Novartis Pharma).	Too rapid infusion may lead to	Deferoxamine is also commonly

	Administration: 1 g deferoxamine (2 vials of 500 mg).	collapse: it should be given in the presence of a physician.	called DFOA or desferrioxamine.
	Medication route: *Intravenous infusion:* Reconstitute with sterile water (5 ml per vial), dilute it with minimum 100 ml normal saline and slowly inject the solution (15 mg/kg/h).		
	Substance: Colloidal aluminium phosphate.	Applied in case of ingestion.	As an example, colloidal aluminium phosphate is supplied from Yamanouchi Pharma (Phosphalugel®).
	Administration: 5 packages of 20 g.		
	Medication route: *Oral administration:* Each package contains 2.5 g of aluminium phosphate.		
Radium (Ra)	**Substance:** Ammonium chloride (Chlorammonic®, Chiesi).	Do not use in cases of metabolic acidosis, uric lithiasis, renal failure, liver failure, nephritis with azotemia.	
	Administration: 6 g ammonium chloride daily in 3 divided doses (4 tablets per dose).		
	Medication route: *Oral administration:* Each tablet contains 500 mg of ammonium chloride.		
	Substance: Barium sulphate (Micropaque®, Guerbet).	Treatment may lead to slight constipation.	
	Administration: 300 g barium sulphate in single dose.		
	Medication route: *Oral administration:* Each vial of Micropaque® contains a solution with 100 g barium sulphate.		
Ruthenium (Ru)	**Substance:** Colloidal aluminium phosphate.	Applied in case of ingestion.	As an example, colloidal aluminium phosphate is supplied from Yamanouchi Pharma (Phosphalugel®).
	Administration: 5 packages of 20 g.		
	Medication route: *Oral administration:* Each package contains 2.5 g of aluminium phosphate.		
Strontium (Sr)	**Substance:** Ammonium chloride (Chlorammonic®, Chiesi)	Do not use in cases of metabolic acidosis, uric lithiasis, renal failure, liver failure, nephritis accompanied by azotemia.	Calcium gluconate is an alternative therapy: give 1 g intravenously over 5-15 minutes. Too rapid injection of calcium gluconate may decrease blood pressure.
	Administration: 6 g ammonium chloride daily in 3 divided doses (4 tablets per dose).		
	Medication route: *Oral administration:* Each tablet contains 500 mg of ammonium chloride.		
Strontium (Sr)	**Substance:** Sodium alginate (Gaviscon®, SmithKline Beecham).		If the solution is not available, chew

	Administration: 10 g sodium alginate in one or two divided doses		several tablets and follow with half a glass of water or other liquid (each tablet contains 0.26 g sodium alginate).
	Medication route: *Oral administration:* Drink 200 ml of the solution containing 5 g sodium alginate per 100 ml.		
Thorium (Th)	**Substance:** Colloidal aluminium phosphate.	Applied in case of ingestion.	As an example, colloidal aluminium phosphate is supplied from Yamanouchi Pharma (Phosphalugel®).
	Administration: 5 packages of 20 g.		
	Medication route: *Oral administration:* Each package contains 2.5 g of aluminium phosphate.		
Tritium (^{3}H)	**Substance:** Water.		Forcing fluids to tolerance will reduce the biological half-life to 1/3 to 1/2 of the normal value.
	Administration: 3-4 litres per day.		
	Medication route: Orally.		
Uranium (U)	**Substance:** Isotonic sodium bicarbonate (1.4% $NaHCO_3$).	The sodium bicarbonate solution is alkaline. Blood pH and electrolytes should be monitored. The use of sodium bicarbonate risks aggravating or unmasking an existing hypokalaemia. Administration of sodium ions to patients with sodium retention should be avoided.	Alternatively, oral administration of two bicarbonate tablets every 4 hours until the urine reaches a pH of 8-9. In case of contamination through the skin also wash with an isotonic 1.4% solution of sodium bicarbonate.
	Administration: 250 ml of isotonic sodium bicarbonate.		
	Medication route: *Intravenous infusion:* Slow intravenous transfusion. Continue over the following days according to the seriousness of contamination.		

Purpose
To provide general guidance on the evaluation of decorporation treatment efficiency.

Discussion
To correct the treatment in accordance with changed conditions of the internally contaminated patient, physicians need the results of evaluation of decorporation treatment efficiency. Follow-up treatment could be based on data from early estimations of intake (bioassay measurements). This can be used as a good tool to verify the effectiveness of internal decorporation methods.

Input
- Information for internal dose assessment (Worksheet F6);
- Results of *in-vitro* bioassay measurements (Worksheet F9);
- Results of *in-vivo* bioassay measurements (Worksheet F11);
- Results of internal dose assessment (Worksheet F7).

Output
- Results of the effectiveness of decorporation treatment (Worksheet D4).

NOTE

The evaluation of the effectiveness of decorporation treatment may be performed by:
- comparing the total measured activity in urine and faeces with treatment to the predicted activity without treatment;
- comparing the activity measured in specific organs or whole body with treatment to the predicted activity without treatment.

Step 1
Calculate the predicted activities in daily urine and/or faeces using the following formula:

$$M^{P}_{E,R}(t) = I \times f_e(t)$$

Where:

$M^{P}_{E,R}(t)$ = predicted daily excretion of radionuclide R for time t after intake, [Bq/day]

I = intake, in Worksheet F6 that is completed before the initiation of the treatment, [Bq]

t = time after intake, [days]

$f_e(t)$ = fraction of the intake of radionuclide R excreted from the body during 24 hours (1 day) before time t after intake, [Bq/day]

NOTE

Values of $f_e(t)$ may be found in Publication 78 of ICRP [12], in the IAEA Safety Reports Series N 18 [13] or on an Internet web site: http://www.nirs.go.jp:8080/anzendb/RPD/gpmd.php (see Appendix XII).

NOTE

Due to the high dispersion of urine and faeces data, it is highly recommended to collect as much data as possible. The excretion rate and biokinetics in the body are subject to natural fluctuations and to individual characteristics, which influence the results.

Step 2
Calculate the ratio between the measured and predicted activities in urine or faeces.

Step 3
Complete Worksheet D4.

Step 4
Calculate the predicted activities in specific organ *T* or whole body using the following formula:

$$M^{P}_{T,R}(t) = I \times f_{T,R}(t)$$

Where:

$M^{P}_{T,R}(t)$ = predicted activity of radionuclide *R*, retained in organ *T* at time *t* after intake, [Bq]

I = intake, in Worksheet F6 that is completed before the initiation of the treatment, [Bq]

t = time after intake, [days]

$f_{T,R}(t)$ = fraction of the intake retained in specific organ *T* or whole body for the time *t* when the measurement is performed, [Bq]

NOTE

Values of $f_{T,R}(t)$ may be found in Publication 78 of ICRP [12], in the IAEA Safety Reports Series N 18 [13] or on an Internet web site: **http://www.nirs.go.jp:8080/anzendb/RPD/gpmd.php** (see Appendix XII).

Step 5
Calculate the ratio between the measured and predicted activities in specific organs or whole body.

Step 6
Complete Worksheet D4 and deliver it to the medical specialist responsible for patient's treatment.

CAUTION

The Step 7 should be followed if the follow-up of decorporation treatment is to be performed by a group of specialists.

Step 7
Complete Worksheet F6 with information on treatment performed. Deliver copies of completed Worksheet F6 together with Worksheet D4 to the requested group of specialists. Instruct the group of specialists to return completed Worksheets D4.

Step 8
Record all the actions in logbook.

NOTE

The medical specialist must register the data provided in Worksheet D4 in order to maintain a database of necessary information. It should be noted that the ratio between the measured and predicted activities in urine and faeces itself does not indicate a measure of the dose reduction by the decorporation treatment.

Purpose

To provide guidance for admission of medically stable casualties to the proper service in the hospital for continuing care appropriate for a specific injury.

Discussion

Once patients have been medically stabilized, and decontaminated if necessary, those with conventional injuries or severe radiation exposure are admitted and transferred to an appropriate hospital service (e.g. haematology, trauma, plastic surgery, burns department). The medical specialist of the appropriate service is responsible for continuing care of the patient. Patients may require surgery for injuries suffered in the emergency or need observation for several days to more completely assess the possibility of high dose from penetrating radiation that could result in bone marrow suppression. Patients may have received high dose to a limited area of the body and may require continuing care of localized skin injuries. Patients exposed to high doses of penetrating radiation will experience bone marrow suppression and will need care by a haematologist.

Since contaminated patients may have internal contamination or residual external contamination on skin, they should be handled using contamination control. Assistance from a Health/Medical Physicist is helpful.

Input

- Patient history and history of exposure (Worksheet D2);
- All medical records;
- Results of dose reconstruction (Worksheet F1) if already available.

Output

- Patients undergoing specific assessment, observation and continued treatment.

Step 1

Brief the staff involved in the assessment, observation, and treatment of the patients. Identify any special procedures including need for radiological contamination control.

Step 2

Determine the possibility of local radiation injury (LRI). If you suspect LRI, photographs of the affected areas should be obtained twice weekly and then daily if signs of radiation injury become evident (or in accordance with any medical evolution that may warrant registration). Photographs should be added to the medical history records of the patient (Worksheet D2).

NOTE

Patients with LRI (hands, feet, thigh, etc.) will experience signs and symptoms of thermal burns except for a striking delay in the onset of clinical changes, from several days to weeks after exposure. The severity of LRI depends not only on the dose and dose rate, but also on the

type of radiation, location, size of the area exposed and geometry of the exposure. Although not usually life threatening, these delayed effects can result in serious injury. The dose dependent onset of clinical signs of skin injury and the dose response relationships are shown in Table D8 [14].

TABLE D8. BASIC CLINICAL SYMPTOMS OF LOCAL RADIATION INJURIES FOR ACUTE EXPOSURE OF GAMMA RADIATION IN HIGH DOSE RATE

Phase of LRI	Severity grade and corresponding dose of exposure, Gy			
	Grade I (mild) 8–12 Gy	**Grade II (moderate) >12– 30 Gy**	**Grade III (severe) 30– 50 Gy**	**Grade IV (very severe) > 50 Gy**
Initial reaction (initial erythema)	Lasts for several hours, can be absent	Lasts from several hours to 2-3 days	Lasts from 2 to 4-6 days. Expressed in all exposed individuals	Expressed in all exposed individuals until the manifestation period.
Latent period	Up to 15-20 days after exposure	Up to 10-15 days after exposure	Up to 7-14 days after exposure	No
Manifestation period	Secondary erythema	Secondary erythema, oedema, blistering	Secondary erythema, oedema, pain syndrome, blistering, erosions, initial radiation ulceration, pus infection	Oedema, pain syndrome, local haemorrhages, necrosis
Conclusion of LRI development	Dry desquamation by 25-30 days	Moist desquamation, with development of new epithelium under rejected layer by the end of 1-2 months.	Development and healing of ulcers is delayed and takes months. Deep ulcers do not heal without surgical treatment (skin grafting).	Processes of injury delineation and rejection are delayed. At 3-6 weeks there is development of gangrene with general intoxication and sepsis. Only timely and radical operation can save life.
Delayed effects (consequences)	Skin dryness, pigmentation	Atrophy of skin, subcutaneous layer and muscles is possible; late radiation ulceration.	Scarring and epithelium defects; deep trophic, degenerative and sclerotic changes; initial necrosis	Effects of amputation, ulcer relapses, contractures.

NOTE

Radiation injury of skin produces lesions similar to the thermal burns. Clinical changes in LRI (hands, feet, thigh, etc.) develop slowly over time (several days to many weeks). In general, exposure to β radiation or low energy X rays causes appearance of signs earlier than exposure to γ radiation or high energy X rays (Table D9) [2,14].

TABLE D9. LOCAL EXPOSURE OF FINGERS OR HANDS: CLINICAL AND DOSIMETRY CONSIDERATIONS

Grade of severity	Dose, Gy; fingers /hand	Period of onset of clinical signs in the acute phase					Time and evolution of late phase effects	Delayed effects
		Primary erythema	Secondary erythema	Blisters	Erosion, ulceration	Necrosis		
I								
γ radiation or high energy X rays	10-17/ 8-15	None	18-24 d	No	No	No	30-35 d Dry desquamation	None or slight skin atrophy
β radiation or low energy X rays	12-18/ 10-15	None or 1 d	12-20 d					None
II								
γ radiation or high energy X rays	18-20/ 15-24	1 d or No	12-18 d	18-22 d	No	No	45-50 d Moist desquamation	Atrophy, late ulcers after 2-3 years
β radiation or low energy X rays	20-30/ 18-25	6-12 h or No	6-14 d	8-15 d				None, or atrophy of skin, depigmentation
III								
γ radiation or high energy X rays	30-100/ 25-80	1 day (may be unrecognized)	6-12 d	8-15 d	20-30 d	No	60-80 d Scar formation	Atrophy of skin, scar-dystrophy changes in skin and joints, deformation of joints, osteoporosis, late ulcers after 1 year and early
β radiation or low energy X rays	35-100/ 30-70	4-6 h	3-7 d	5-10 d	10-18 d		50-70 d	Atrophy of skin, depigmentation, telangiectasia
IV								
γ radiation or high energy X rays	>100- >80	4-6 h	1-4 d	3-6 d	6-10 d	6-10 d	No healing	Secondary infection, sepsis, osteomielitis, pathological breaks
β radiation or low energy X rays	>100- >70	1-2 h	0-4 d	3-5 d	6-7 d	6-10 d	60-80 d Scar formation	Atrophy of skin, depigmentation, telangiectasia, hyperkeratosis

Step 3

Obtain a careful history to determine the possibility of acute, high dose radiation exposure that may lead to acute radiation syndrome (ARS).

NOTE

The treatment course for ARS will depend on the particular syndrome. The cardiovascular and neurovascular syndromes are invariably fatal. The gastrointestinal syndrome is usually fatal, particularly when resulting from higher doses, but it is not invariably so. Survival from the haemopoetic syndrome is much more likely. Appropriate treatment will assist recovery from the haemopoetic syndrome and lower dose gastrointestinal syndrome and will improve survival chances. Treatment to palliate symptoms should be given wherever possible, even when the chance of survival is poor. Prolongation of life has been seen with effective palliative treatment [15].

Step 4

Decide on necessary treatment of patients with ARS based on the symptoms, evolution of medical status, laboratory results and medical needs, but not on radiation dose. Use Table D10 for determination of treatment arrangements.

TABLE D10. DETERMINATION OF TREATMENT ARRANGEMENTS BASED ON PATIENT'S SYMPTOMS

Symptoms	Treatment
No nausea, vomiting or diarrhoea. Lymphocyte count above 1000 mm^{-3} at 48 hours. Probably no life-threatening injury.	Observe periodically for any change in clinical status.
Nausea, mild vomiting; conjuctival redness and erythema. Lymphocyte count between 700 and 1000 mm^{-3} at 48 hours.	Probably injury with mild grade of severity; plan for therapy.
Pronounced nausea and vomiting; possible diarrhoea, conjuctival redness and erythema. Lymphocyte count between 400 and 700 mm^{-3} at 48 hours.	Probably life-threatening injury; plan for maximum therapy in specialized hospital.
Prompt severe vomiting and bloody diarrhoea; erythema and hypotension. Lymphocyte count between 100 and 400 mm^{-3} at 48 hours.	High probability of lethal outcome. Provide with maximum therapy in specialized hospital.
Loss of consciousness. Prompt severe vomiting and bloody diarrhoea; erythema and hypotension. Lymphocyte count below 100 mm^{-3} at 48 hours.	Low probability of survival. Provide with supportive therapy.

Step 5

Request data on dose assessment from Health/Medical Physicist and make adjustment of protocol of treatment (if necessary).

Step 6

Continue decorporation treatment using Procedure D3 (if necessary).

Step 7

Determine the capability for continuing care or need to transfer patient to Referral Hospital depending on patient's prognosis and required treatment (from Step 4).

Step 8

Transfer patients to Referral Hospital as necessary using Procedure D6. Provide complete set of medical records for all patients to be transferred.

Step 9

Continue care for patients remaining in the appropriate service of the hospital and discharge when hospitalization is no longer required.

Step 10

Make necessary arrangements, and advise discharged patients regarding any need for outpatient care or long term follow-up.

NOTE

Consider design of discharge sheets with basic information about radiation exposure and accurate information about the long term health effects of radiation exposure. Customize and relate these possible effects to the specific situation and individual.

Purpose
To provide guidance for transfer of seriously injured or overexposed patients to a Referral Hospital.

Discussion
When the patient's medical/radiological condition exceeds the medical care capabilities of the receiving hospital, transfer to a suitable Referral Hospital is necessary. In this regard patients fall into four categories:

1. Patients seriously overexposed at doses leading to acute radiation syndrome (ARS) with experience of immunosuppression, gastrointestinal, or pulmonary problems days to weeks post exposure, whose medical management requires highly specific care;
2. Contaminated patients with trauma/illness, whose medical management requires care under the direction of a specialist;
3. Seriously overexposed and contaminated (externally/internally) with trauma, whose medical management requires care under the direction of a specialist; and
4. Seriously injured patients, neither exposed nor contaminated, whose medical management requires care of a specialist.

Input
- Results of radiological survey of the patient (Worksheet D1);
- Medical information form (Worksheet D2);
- Results of decontamination (Worksheet D3);
- Results of decorporation (Worksheet D4);
- Results of dose reconstruction (Worksheet F1) if already available;
- Decision on the patient's transfer to the Referral Hospital.

Output
- A copy of all medical and radiological data (Worksheets D1, D2, D3, D4, F1);
- Transfer of patient to the Referral Hospital.

Before the transfer: actions to be taken by Hospital Emergency Department Response Team

Step 1
Identify, notify, and finalize arrangements with respective Referral Hospitals prior to patient transfer.

Step 2
Prepare the patient to be transferred using contamination control procedures if necessary. Use Table D11 as guidance for arranging the contamination control procedures. Prepare a copy of all documentation.

NOTE

If patient's radiological status requires, a Health/Medical Physicist should accompany each patient during transfer and admission to the Referral Hospital. This will insure contamination control during transport. A copy of medical and radiological data should accompany all patients transferred to the Referral Hospital.

TABLE D11. CONTAMINATION CONTROL PROCEDURES FOR DIFFERENT CATEGORIES OF PATIENTS

Patients:	Necessity of control procedure	Technique/Remarks
With no confirmed radiation exposure or contamination	No	Lack of radiation injury, especially contamination, should be clearly identified in the respective chart of each patient.
Exposed only	No	
With no confirmed absence of radioactive contamination	Yes	Wrap the patient in a sheet/ blanket or cover limited areas of contaminated body surfaces or wounds with waterproof coverings. All coverings should be taped in place. Use a surgical head cover and booties if necessary.
Externally contaminated	Yes	
Internally contaminated	Yes	Vomiting can spread contamination to equipment, and attending staff. Special precautions usual to prevent the external spread of internal contaminants should be made.

Step 3

Initiate the transfer of the patients.

Upon arrival: actions to be taken by Health/Medical Physicist

Step 4

Provide a complete radiological report on the contaminated patients and assurance that other patients pose no radiological hazard to the attending staff.

Step 5

Collect any contaminated sheets, blankets, and medical supplies used for patient transfer, place these items in plastic bags, label them accordingly, and return them to a secure, designated storage site.

Step 6

Conduct a careful radiological survey of the ambulance transfer crew, the ambulance, and equipment prior to release for return to regular service. If any contamination is found supervise the decontamination.

After transfer: actions to be taken by receiving physician at the Referral Hospital

Step 7

Brief the Health/Medical Physicist of the Referral Hospital on duty to take over exposure/contamination control, and brief the attending staff.

NOTE

Patients transferred to a Referral Hospital may require additional decontamination of skin and wounds. Body excreta should be collected for radiological analysis. The hospital Health/Medical Physicist should assist in decontamination procedures and control of samples.

Performed by:	**PROCEDURE D7**	
Decontamination Team, Dosimetry Team	**RADIOLOGICAL SURVEY OF VICTIM ON SCENE AND AT HOSPITAL**	*Page 1 of 6*

Purpose
To monitor emergency victims for personal skin and clothing contamination.

Discussion
Personal monitoring of the external contamination of victims should start as soon as possible. The results of monitoring will allow the prevention of the spread of contamination and the performance of decontamination procedures. Therefore, the initial radiological survey needs to start on scene of the emergency and be continued in the hospital. External contamination is assessed by direct monitoring of skin and clothing. Internal contamination is usually checked by monitoring of biological samples taken from the person or by direct measurement (see Section F).

Precautions
For persons who require urgent medical attention and subsequent urgent transportation and who may be contaminated, priority should be given to their medical condition and its treatment even if this means that first aiders, ambulance officers, paramedics or other medical staff may become contaminated as a consequence (if not properly prepared). If medical personnel use their standard personal protection procedures for handling bleeding patients, this will assist in contamination control.

Input
- Victims on site or at the hospital.

Output
- Results of radiological survey of the victim on scene (Worksheet C1) or at the hospital (Worksheet D1).

Step 1
Perform quality control checks on contamination monitor [4].

Step 2
Turn contamination monitor audio on and place probe in a light weight plastic bag or cover to prevent it from being contaminated. Do not cover the probe window.

NOTE

This is desirable but not mandatory. The monitor should have an active area of at least 20 cm^2 to give useful results at just acceptable levels.

Step 3
Determine and record the background radiation level periodically at the location where the monitoring is to take place (Worksheet C1 or D1).

CAUTION

If the meter reading at the scene of the emergency is greater than ten times what would be considered a 'normal background' reading, arrange monitoring in a better shielded location (if possible). If victim's condition makes it impossible to move him/her to an area of lower background radiation, monitoring should then be carried out where the victim is at the time with any shielding available. If the person doing the monitoring stands between the area of high background radiation and the victim, this helps shield the monitor from the higher levels. However, it does not help much in case the victim is lying on the ground and the person performing the monitoring is standing.

Step 4

After getting request from medical personnel, perform personal monitoring of the victims.
On the basis of the results of the survey, perform radiological triage according to the following guidance:

- Consider areas that show more than 2–3 times the normal background level as contaminated and act appropriately.

NOTE

Comparison with normal background level (expressed in appropriate units) is very practical as it allows radiological triage using any type of instrument.

CAUTION

This approach is valid only for radionuclides present in the environment under normal circumstances. For some radionuclides (e.g. iodine), which are not normally found in the environment, any level of activity above zero represents contamination.

- If alpha emitters are present and if the reading is less than twice background radiation level, the person is not contaminated to a medically significant degree.

CAUTION

Precautions should be made to prevent internal contamination of victims with alpha emitters or low energy beta emitters (such tritium) by inhalation/ingestion. Therefore, even a low level of contamination, which is not medically significant, should be treated accordingly (removal of clothes, etc.).

NOTE

Personal monitoring should not interfere with medical actions to stabilize victims' condition or transport victim with life-threatening injuries. Radiological survey at the scene of the emergency should be done in co-operation with medical personnel.

NOTE

In cases of potential contamination of a large number of people and the need to monitor them, it is necessary to establish a place to perform the monitoring and supply it with trained personnel, necessary monitoring equipment, decontamination facilities and supplies, and record keeping supplies. Access to this place should not interfere with access to the hospitals accepting casualties. Athletic fields, stadiums, and community centres could be used for this purpose.

Monitoring of not seriously injured or uninjured victims

Step 5

Place the probe about 1 cm from the person's body being careful not to touch him/her. Starting at the top of the head, move the probe downward on one side of the neck, collar, shoulder, arm, wrist, hand, underarm, armpit, side, leg, cuff, and shoe. Monitor the insides of the legs and the other side of the body in the sequence indicated in Figure D2. Monitor the front and back of the body. Pay particular attention to the feet, seat, elbows, hands and face. The probe should be moved at a speed of approximately 5 cm per second. Any contamination will be detected primarily using the audio response. If in a noisy environment earphones may be appropriate to listen to the instrument audio response.

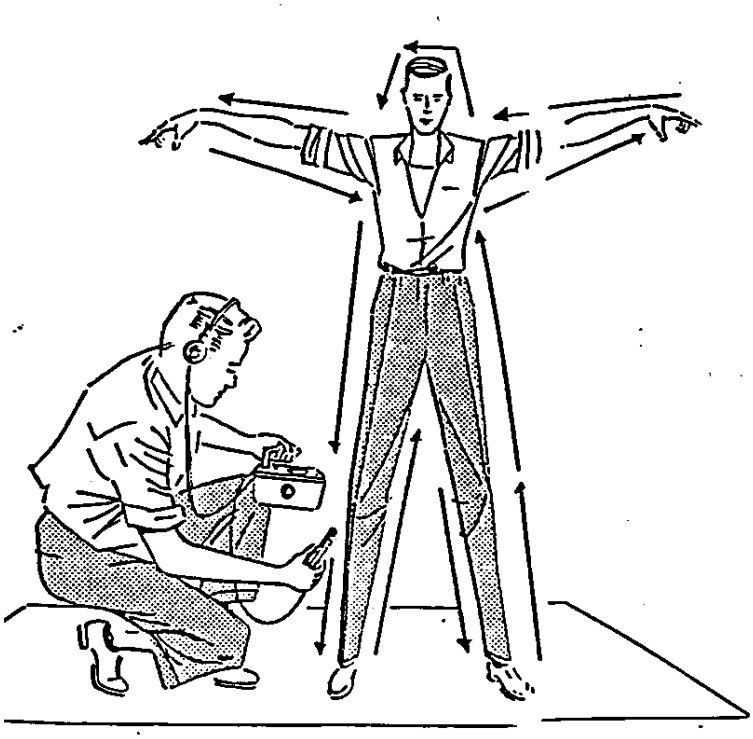


FIG. D2. Frisking technique

NOTE

The parts of the body most likely to be contaminated externally are the hands and face (including body orifices), with less likely areas being the head, neck, hair, forearms, wrists and torso. If the radioactive material is in liquid form, it could penetrate clothing, thereby increasing the possibility of contamination being on some of these latter parts of the body.

NOTE

For skin and clothing, measurements may be averaged over 100 cm^2, for hands they may be averaged over 30 cm^2 and for fingertips they may be averaged over 3 cm^2.

The simplest way to average the measurements of surface contamination is to use a monitor of surface contamination with the relevant sensitive area of probe. Place the probe less then 0.5 cm from the person for alpha monitoring. However, alpha monitoring of normal clothing is very unreliable.

In cases of urgency, the exposed skin is to be monitored and then the subject asked to change clothing. The potentially contaminated clothing can then be monitored later. The subject needs to be helped to change and given gloves to stop transfer if serious contamination is suspected.

Monitoring of seriously injured victims

NOTE

Monitoring at the scene of the emergency is to be done only by request of medical personnel, depending on victim's condition.

Step 6

Perform a rapid contamination assessment using general guidance from Step 5. Usually, a seriously injured person will be monitored in the lying position. Survey the parts that it is possible to access (front parts of the head, hands, legs, and body). Survey back side of the body only if possible by victim's condition. Use possibility to survey back side of the body if the victim is turned by medical personnel for the medical purposes

Step 7

If the patient requires transfer to a hospital immediately, make sure that the medical team will inform the hospital upon arrival that radiological survey was not performed at the scene of the emergency.

Monitoring of wounds

NOTE

The major problem is likely to be locating the radioactive material within the wound so that decontamination can be carried out effectively. Specialized wound probes (scintillation or semiconductor detectors) provide a good sensitivity to assess the gross activity at the wound site. The evaluation of internal dose due to wound contamination is not possible on the basis of measured activity in the wound. Methods of *in-vitro* or *in-vivo* bioassay are to be used for dose assessment. Information about contamination of the wound may give an idea how to interpret the bioassay measurements.

Step 8

Monitor the wound using specialized wound probe (if possible). The wound should be surveyed uncovered. If the wound is dressed, the dressing should be left in place unless removed by medical personnel.

NOTE

Alpha particles could be absorbed by the wound's fluid, which will lead to an incorrect indication of the presence of alpha emitters. In these cases, the wound should be wiped carefully with sterile gauze and then dried by blotting before measurement. All material used for blotting dry should be monitored as a double check.

Monitoring of body orifices

Step 9
Monitor the areas near eyes and nose, initially using monitors with large windows of 30–100 cm^2 area. Then use monitors with smaller windows to pinpoint regions of contamination.

Step 10
Perform radiological survey of nasal and oral swabs taken on moist, clean cotton-tipped applicators. Swabs should be taken within about 10 minutes of the emergency because of the rapid absorption of the radionuclides from the nose and mouth to the body.

NOTE

If only one nostril is contaminated, most likely the nose has been touched with a contaminated finger. The possibility of inhaled material is reduced.

If the results of swab survey show several hundred and more cpm, there is a possibility of a large inhalation. If the results show about tens cpm, the inhalation is probably low. This interpretation of the results can be used only for the initial assessment.

If alpha emitters are involved, swabs should be dried before measurement is performed.

After monitoring

Step 11
Compare results of monitoring with operational intervention levels (OILs). Where surface contamination derived limits are not specified by the national competent authority, the following default values are suggested (Table D12). Take appropriate actions (within your expertise) as indicated in Table D12. Perform decontamination following Procedure D2.

NOTE

If the detector cannot distinguish between alpha and beta, use a piece of paper between the detector and the source. If the reading drops, alphas can be considered present.

Step 12
Record results on Worksheet C1 or D1. Measured area (active surface of the detector) should be also recorded.

Step 13
All personal belongings should be monitored including watches, handbags, money, TLDs, and weapons. Contaminated items should be bagged and labelled for decontamination. Contaminated personal clothing may be removed, bagged and labelled and substitute garments provided (usually by public welfare agencies).

NOTE

Receipts may need to be issued for confiscated items.

TABLE D12. SKIN CONTAMINATION OPERATIONAL INTERVENTION LEVELS (OILS)

OIL	Alpha	Beta/gamma		Low toxicity beta/gamma[10]	Actions
	Bq/cm^2	Bq/cm^2	mSv/h[11]	Bq/cm^2	
OIL-1	>1E3	2.5.17.1. > 1E4	2-3 μSv/h measured in low background area[12]	>1E6	***Required*** - Prevent inadvertent ingestion[13]. - Limit spread of contamination. - Decontaminate. - Give stable iodine prophylaxis if radioiodine is involved. - Perform medical examination and indicated treatment. - Registry for long term medical follow-up. - Perform comprehensive psychological counselling (in particular for pregnant women).
OIL-2	>1E2	2.5.17.2. > 1E3	0.2-0.3 μSv/h measured in low background area	>1E5	***Advisable*** - Prevent inadvertent ingestion. - Limit spread of contamination. - Decontaminate. - Give stable iodine prophylaxis if radioiodine is involved. - Consider registry for long term medical follow-up. - Perform comprehensive psychological counselling (in particular for pregnant women).
OIL-3	> 1E1	>1E2	Not detectable	>1E4	***Optional*** - Decontaminate or advise to shower and wash clothing when possible. - Assure them that there is no significant health risk and inform them where to get additional information. - Release.
	Detectable and < 1E1[14]	Detectable and < 1E2[14]	2.5.17.3. Not detectable	Detectable and < 1E4[14]	***No actions*** - Assure people that there is no significant health risk and inform them where to get additional information. - Release.

Step 14

Record all actions in the logbook.

[10] H3, Cr-51, Fe-55, Ni-63, Tc-99m.
[11] Ambient dose equivalent rate H* measured at 10 cm.
[12] Low background dose rate assumed to be about 0.1 μSv/h.
[13] To include those treating/decontaminating the contaminated individual.
[14] Levels about 1/10 of these are typically used as limits in industry to promote good radiation practice – but do not indicate a radiation hazard.

SECTION E
PSYCHOLOGICAL SUPPORT

Caution: *The procedures in this section should be adapted to reflect national, local and hospital conditions and capabilities, including protocols of medical treatment for which they will be applied.*

Purpose

To provide general guidance on psychological support at different stages of preparedness and response to radiation emergencies.

Discussion

It is clearly recognized that knowledge of radiation and its effects can reduce stress. While the 'stressor' or the causative agent cannot be removed, effort is needed to change the way in which it is perceived. Psychological reactions to radiation could be prevented, decreased or relaxed using different methods applied before, during or after the emergency or malicious act. In general, a malicious act involving radioactive material will generate more psychological distress than other types of radiation emergency.

Appropriate officials at the national and local levels need to perform the actions needed to arrange psychological support. These actions are to be palnned at the stage of preparedness.

Input

- Analysis of possible emergency situations.

Output

- Justified need for system of psychological support for different categories of affected people in case of radiation emergency.

Step 1

Use Table E1 to determine for what situation and categories of people one has to prepare (to plan) psychological support in a radiation emergency situation.

TABLE E1. GUIDANCE ON PSYCHOLOGICAL SUPPORT

Type of radiation emergency	Psychological support needed for:		
	Victims	General public	Emergency responders
Reactor (NPP, RR)	Yes	Yes	Yes
Criticality	Yes	Yes	Yes
Lost/stolen dangerous sources	Yes	Yes	Yes
Transport	Yes	Yes	Yes
Nuclear power satellite re-entry	Yes, if any	Yes	Yes
Laboratory	Yes	No	Yes
Use or misuse of industrial dangerous sources	Yes	No	Yes
Misadministration in medical diagnosis and therapy	Yes	No	Yes
Malicious acts involving radioactive material	Yes	Yes	Yes

NOTE

Individuals or groups needing such support will depend on the nature and magnitude of the radiation emergency.

Step 2

Depending on results of Step 1, go to the appropriate procedure.

Psychological support at:	Procedure:
preparedness stage	E1
response stage - for the public	E2
response stage - for the patients	E3
response stage - for the emergency workers	E4

Purpose

To provide general guidance on psychological support arrangements at the stage of preparedness.

Discussion

It must be taken into account that preparedness requirements are inconvenient for people because they demand physical and mental efforts from population (not usually aware that it is necessary), and it will not be easy to engage them.

Input

- Analysis of possible emergency situations.

Output

- System of psychological support for different categories of affected people in case of radiation emergency.

Step 1

Establish education programme for the public. Include information about:

1. radiation:
    - what radiation is;
    - how it can be readily detected;
    - natural occurrence of radioactive material;
    - what radiation can and cannot cause;
    - particular examples of threshold doses for specific effects;
    - radiation and pregnancy; and
    - how to reduce exposure using protective actions.
2. specific plans for the community:
    - risk of an emergency;
    - types of radiation emergencies possible; and
    - protective action planned for the facility and for the public.

NOTE

Use different ways of providing information to the public (e.g., leaflets, brochures, calendars, and phone books). Use different forms of materials, like publications, audio, and video.

Step 2

Establish specific programmes for different categories of affected people based on Step 1.

Step 3

Provide general educative materials for different categories of professionals (e.g., physicians, emergency responders, public officials, nurses, teachers, psychologists, and the media). These professionals could be used in an emergency to communicate with the public in order to decrease psychological stress among public.

Step 4

Make provisions to take precautions to avoid violating religious, cultural or social customs when doing surveys, decontamination, etc. Make arrangements for both male and female assistance. Plan to provide privacy as appropriate.

Step 5

Plan to have trusted, informed individuals at survey/counselling centres to provide answers and to calm worried persons.

Step 6

Make arrangements to ensure that parents and children are not separated while implementing protective actions. Parents should know where school children would be taken in event of an emergency during school hours. Recognize that displacement from home is especially traumatic for the elderly.

Purpose
To provide general guidance on psychological support for the public during an emergency.

Discussion
The widespread public anxiety associated with severe radiation emergencies appears to be out of proportion to the radiation induced health effects. This is especially true when malicious acts involving radioactive material must be considered. Decision makers must take these effects into account in emergency management because the reality of public distress has direct relevance for policy makers, and for public health and medical personnel.

Input
- Analysis of real emergency situations.

Output
- Minimized effect on the mental health of public during an emergency.

Psychological support for public during acute phase of emergency

Step 1
Provide simple and clear instructions regarding protective actions (within your level of responsibility as indicated in Emergency Plan).

NOTE
Avoid making decisions on protective actions which will lead to separation of families.

Step 2
Ensure trusted and informed leadership within public health activities to provide psychological support for public during emergency.

Step 3
Establish and staff counselling centres at monitoring and evacuation centres.

Step 4
If decontamination of uninjured persons is necessary, provide clear instructions for self-help and provide privacy.

Step 5
Provide special assistance for individuals with pre-existing mental health problems if they are unable to cope with the situation.

Step 6
When necessary, arrange medical counselling for concerned expectant mothers.

Step 7
Be honest in communications and prevent conflicting messages being conveyed by the media.

Step 8

Resist pressure to introduce protective actions within the public domain at levels that are well below pre-established national criteria and international guidelines.

Psychological support for public after acute phase of the emergency

Step 9

Establish a special social and psychological support programme to provide help for affected individuals. It could be beneficial to:

- encourage individuals exhibiting continuing signs of stress to meet in groups with a counsellor to discuss their concerns.
- participate in a group activity that is designed to serve a useful purpose in the community.
- involve communities in the post emergency activities.

NOTE

Most children will adapt satisfactorily if parents accept and adapt to the situation satisfactorily. If parents have problems adapting, plan on providing counselling for children. Experience has shown that mothers of young children will exhibit signs of stress even years after a perceived risk.

Step 10

Make provisions for continued psychological support for individuals doing clean-up work after the emergency. Families of these individuals might also need counselling.

NOTE

Some individuals will become especially concerned about their health and will seek repeated medical evaluation. These individuals may have symptoms with or without evidence of disease. If they are disease free, they need to be encouraged to ‘monitor their health’ by regular medical examinations (within standard national programme of medical care).

Performed by:	**PROCEDURE E3**	
Emergency Manager	**PSYCHOLOGICAL SUPPORT FOR EMERGENCY RESPONDERS**	*Page 1 of 1*

Purpose
To provide guidance on psychological support for emergency responders.

Discussion
During a radiation emergency, emergency responders would be expected to perform their duties under stressful conditions. Emergency responders must do their work, even though they are anxious and very concerned about their own safety and the safety of their families. Responders who are unable to deal with such stress could develop mental health problems such as post traumatic stress disorder (PTSD), substance abuse or depression.

Input
- Response to emergency situation;
- Action to be taken by emergency responders under stressful conditions.

Output
- Minimized effect on the mental health of emergency responders.

Step 1
Plan enough teams and workers so that work in shifts (if needed) can be arranged. Plan adequate rest periods. Enforce rest periods if necessary.

Step 2
Arrange an initial briefing. Ensure use of protective clothing and dosimeters, if appropriate. Explain objectives (tasks) of the mission, possible hazard the responders may face, and show summary of radiation protection and contamination control procedure they have to follow.

Step 3
Brief emergency responders about the emergency situation before each shift and periodically during shifts.

NOTE

When possible, allow emergency responders to check on the status of their families.

Step 4
If an emergency responder is given a new task, ensure brief instructions and initial assistance so the responder is not stressed with uncertainty regarding the task.

Step 5
Hold debriefing meeting at the completion of emergency response activities. Record psychological problems faced.

Purpose

To provide guidance on psychological support for the patients affected by radiation at the hospital level.

Discussion

Persons involved in serious radiation emergencies may experience many situations during hospitalization that contribute to stress and depression. Hospitalization may be lengthy and require strict isolation from family and friends. Such patients may be subjected to repeated tests and their privacy may be invaded in the process. They may fear death or experience altered self-image. For those who survive, there may be fear of post emergency physical contact with loved ones or concern about procreation. Long periods of pain may result in narcotic addiction and lengthy rehabilitation. The health care provider must be prepared to listen to the patients concerns, share messages with family members, and otherwise answer questions honestly with sympathetic concern for individual patient.

Performance of steps described in the procedure will prevent or minimize the symptoms of anxiety, fear, denial, anger, depression, dependency, etc. from patient's side.

Input

- Medical information form (Worksheet D2);
- Emergency history.

Output

- Minimized effect on the mental health of the patients.

Actions of Emergency Medical Manager:

Step 1

Arrange the health care at the hospital taking into account the following general considerations:

- Avoid placing patient in a hospital where language, foods and customs are different or where significant others are unable to visit;
- Provide information about radiation for care-givers;
- Counsel anxious care-givers;
- Provide pastoral visits if requested by patient or family;
- Consult psychiatrist if the patient has pre-existing mental health problems; and
- If possible, include psychologist in the Hospital Emergency Department Response Team

Step 2
Assign one physician, trusted by the patient and family, to be in charge of patient care. Medical consultants need to provide assistance and guidance to this physician.

Actions Physician:

Step 3
Provide the patient with information regarding emergency history (if necessary), conditions, tests and treatment procedures.

Step 4
Provide a means to allow patient-family communication. Provide instructions to family regarding isolation procedures. Reassure family that externally exposed person is not contagious.

Step 5
Involve the patient (when possible) in participation in decisions about care.

Step 6
Allow patient to provide self-care when possible.

Step 7
Provide patient privacy as much as possible and protect patient from the media.

NOTE

The media will want to interview patients in the hospital and seek photo opportunities. Patients' consent is needed for these actions. It should be remembered, that patients confidentiality and care comes first. Comfort of nearby patients must also be considered.

SECTION F

DOSE ASSESSMENT

Caution: *The procedures in this section should be adapted to reflect national, local and hospital conditions and capabilities, including protocols of medical treatment for which they will be applied.*

Purpose

To provide an overview of dose reconstruction for medical purposes and of steps to be taken for estimating the doses received in emergency conditions by emergency workers and/or members of the public.

Discussion

Evaluation of different types of possible medical consequences of radiation exposure (deterministic and stochastic) and their effective management requires different types of dosimetric information. Detriment related to occurrence of stochastic effects can be evaluated with the use of effective dose. The probability of occurrence of stochastic effects in a particular organ or tissue could be evaluated with the use of radiation weighted dose in an organ or tissue defined as the product of the averaged absorbed dose in the organ or tissue and the radiation weighting factor w_R [16]. The ICRP in its forthcoming recommendations supersedes the equivalent dose by this dosimetric quantity for evaluating the stochastic effects of radiation. The unit of radiation weighted dose is *sievert (Sv)* [17]. For evaluating deterministic effects developing due to exposure to radiation of different quality, the RBE-weighted absorbed dose is used. The RBE-weighted averaged absorbed dose in the organ or tissue (RBE-weighted absorbed dose) (AD_T) is defined as a product of averaged absorbed dose in organ or tissue and the relative biological effectiveness (RBE). The proposals of how to adjust doses taking account of radiation quality with regard to deterministic effects were discussed in NUREG Report 4214 [18] and in ICRP Publication 92 [17]. The unit used to express the RBE-weighted absorbed dose in SI is $J \times kg^{-1}$ and is called the *gray-equivalent* (*Gy-Eq*)*)* [17, 18, 19].

In general, the RBE for deterministic effects depends on such factors as the quality of radiation, irradiated organ or tissue, committed effect, and dose rate. Values of the RBE of radiation for severe deterministic effects used in this manual are presented in Table F1.

TABLE F1. RBE OF RADIATION FOR SEVERE DETERMINISTIC EFFECTS USED IN THE MANUAL

Radiation	RBE
Photons (gamma- and X rays)	1
Electrons and positrons, including β^- and β^+ particles	1
Neutrons	3
Alpha particles irradiating internally lung	7
Alpha particles irradiating internally red marrow	2
Alpha particles irradiating internally colon	0
Iodine-131 irradiating internally thyroid gland	0.2
Alpha particles irradiating offspring	10

After defining the level of radiation exposure (assessing the dose), the dose is to be compared with the generic dose criteria, established in advance for further medical/public health actions as listed in Table F2.

TABLE F2. GENERIC REFERENCE LEVELS FOR MEDICAL ACTIONS DURING RADIATION EMERGENCY

Generic reference levels	Action	
External exposure AD_{Torso}[15]:>1 Gy-Eq (brief exposure) AD_{Foetus}[16]:>0.1 Gy-Eq (brief exposure) AD_{Tissue}:>25 Gy-Eq at 0.5 cm depth (contact - brief exposure)[17] AD_{Skin}:>10 Gy-Eq to 600 cm^2 [18] (brief exposure) **Internal exposure** $AD(\Delta)_{Red\ marrow}$: >0.2 Gy-Eq for intake of actinides (Δ = 30 days[19]) $AD(\Delta)_{Red\ marrow}$: >2 Gy-Eq for intake of radionuclides other than actinides (Δ = 30 days[19,20]) $AD(\Delta)_{Thyroid}$: >2 Gy-Eq (Δ = 30 days[19,21]) $AD(\Delta)_{Lung}$: >30 Gy-Eq (Δ = 30 days[19,22]) $AD(\Delta)_{Colon}$: >20 Gy-Eq (Δ = 30 days[19]) $AD(\Delta)_{Offspring}$:>0.1 Gy-Eq (Δ = period of *in utero* development)	- Immediate medical examination, consultation and indicated treatment - Recommendation for immediate decontamination (if applicable) - Immediate decorporation (if applicable) - Prescription of stable iodine (if applicable[23]) - Contamination control - Comprehensive psychological counselling - Recommendation for accurate calculation of organ specific dose (if applicable)	- Registration for long term medical follow-up
E_{Tot}: > 100 mSv in weeks - month $H_{Thyroid}$: > 50 mSv in weeks	- Recommendation for accurate calculation of organ specific dose (if applicable) - Advice and basic counselling	- Screening, based on individual dose, to determine if registration is necessary for long term medical follow-up
H_{Foetus}:> 100 mSv in months	- Basic counselling to allow informed decision to be made based upon individual circumstances.	
E_{Tot}:<10 mSv in a year[24] H_{Foetus}: <100 mSv in months $H_{Thyroid}$: < 50 mSv $H_{Any\ other\ organ}$: < 100 mSv in a year	- Basic public information that there is no statistically demonstrated risk	

[15] Is used to address external exposure to the red marrow, lung, small intestine, gonads, lens of eye, and thyroid from irradiation in uniform field of strongly penetrating radiation. This would also be the dose of strongly penetrating radiation typically monitored by a personal dosimeter.

[16] To be compared with value of AD_{Torso} for pregnant woman.

[17] Dose delivered to depth of 0.5 cm in tissue from contact (e.g. source carried in hand or pocket).

[18] To approximate more than 1/3 of the surface of the body. The dose is to skin structures at a depth of 50 mg/cm^2 (or 0.5 mm) under the surface at which long term effects are expected.

[19] $AD(\Delta)$ is the dose delivered over the period of Δ by the threshold intake (I_{05}). The threshold intake is the amount that will result in the health effect in 5% of exposed people.

[20] The actinides and other radionuclides have different biokinetic processes, hence different dynamics of dose formation in red marrow due to internal exposure. The difference of $AD(\Delta)_{Red\ marrow}$ among radionuclides (actinides and other than actinides) reaches a factor of about 50, while the difference within each group doesn't exceed a factor of 3. Therefore, radionuclides have been divided into two groups. This allowed avoiding overconservative single GRL, established on the lowest level.

[21] Only for internal exposure from radionuclides absorbed by thyroid as a critical organ: radioactive isotopes of tellurium, iodine, technetium, and rhenium.

[22] For purposes of this manual "Lung" means the gas-exchange region of respiratory tract.

[23] Stable iodine is prescribed: a). if radioactive iodine is involved in the emergency, and b). only within short period after the internal intake of radioactive iodine.

[24] Includes dose from all sources.

Input

- Recommendations from the field Radiological Assessor or Incident Commander (On-scene Controller);
- Emergency history (e.g. type of exposure, radiation sources or material involved, chronology of events, persons involved) from Worksheets A2, C2;
- Results of environmental monitoring (if available);
- Results of radiological survey on site and at the hospital (Worksheets C1, D1);
- Dosimeters readings (Worksheet D2).

Output

- Results of dose assessment to the individual (Worksheet F1);
- Recommendations for further action.

Step 1

For every person admitted to hospital, confirm that evaluation of the following observable parameters was done in the field by Radiological Assessor:

- emergency conditions
- skin and closing contamination
- dosimeter readings
- thyroid monitoring (if applicable).

Use recommendations from the field Radiological Assessor or Incident Commander (On-scene Controller) for further actions. If the evaluation was not done, conduct evaluation (based on the information available) and take appropriate actions. See Table F3 for details.

Step 2

For affected people suspected to be at risk for development of deterministic effects, estimate RBE-weighted absorbed dose of external exposure and committed RBE-weighted absorbed dose of internal exposure delivered over time Δ in organ or tissue concerned using formulas below.

Internal exposure

$$AD_T^{Int}(\Delta) = AD_T^{Inh}(\Delta) + AD_T^{Ing}(\Delta),$$

Where:

$AD_T^{Int}(\Delta)$ = committed RBE-weighted absorbed dose of internal exposure: an RBE-weighted absorbed dose delivered to organ or tissue *T* over time Δ after intake, [Gy-Eq]

$AD_T^{Inh}(\Delta)$ = inhalation committed RBE-weighted absorbed dose: an RBE-weighted absorbed dose delivered to organ or tissue *T* over time Δ after intake, [Gy-Eq], (from Step 3 of Procedure F5)

$AD_T^{Ing}(\Delta)$ = ingestion committed RBE-weighted absorbed dose: an RBE-weighted absorbed dose delivered to organ or tissue *T* over time Δ after intake, [Gy-Eq], (from Step 3 of Procedure F5)

Δ = duration of time period for estimation committed RBE-weighted absorbed doses after intake of radioactive material. It is equal to 30 days for lung, red marrow, and colon and to time of *in utero* development for offspring.

TABLE F3. OPERATIONAL PARAMETERS FOR ACTIONS IN HOSPITAL

Parameter	Result of evaluation	Action recommended
Emergency conditions	Indication for a potential of a serious exposure, which could result in deterministic effects (e.g. the person was very close to the site of emergency or in the smoke of a fire/explosion involving a dangerous dispersible source, was near a criticality or was handling a ruptured dispersible dangerous source)	Estimate RBE-weighted absorbed dose (go to Step 2)
	Indication for potential of inhalation	Arrange for collection of urine samples and nose blows (go to Procedure F6)
	Indication for potential of ingestion	Arrange for collection of urine and faecal samples (go to Procedure F6)
	Indication for potential of internal contamination	Perform *in-vivo* monitoring of whole body, lungs or thyroid (go to Procedure F7)
	Indication for external exposure to photons as the major pathway	Arrange for sampling for cytogenetic analysis or EPR dosimetry [20] (go to Procedure F2)
	Indication for external exposure to neutrons as the major pathway, e.g. in the case of criticality emergency	Arrange for measurements of ^{24}Na in a blood sample or in whole body (by means of Whole body counter) (go to Procedure F3)
		Perform neutron dose assessment (go to Procedure F4)
	Indication for exposure of foetus	Perform assessment of RBE-weighted absorbed dose for the foetus (go to Procedure F5, Step 4).
Skin or clothing contamination	> 1E3 Bq/cm^2 alpha contamination > 1E4 Bq/cm^2 beta/gamma contamination > 1E6 Bq/cm^2 low toxicity beta/gamma contamination	Report to physician for performing of required decontamination Look at Table D12 for details of actions to perform.
Dosimeter reading Hp (10)	Reading is greater than 500 mSv	Estimate RBE-weighted absorbed dose (go to Step 2). Decide on necessity of cytogenetic analysis or evaluation of inhalation/ingestion on the basis of emergency history
Presence of radioactive iodine in thyroid	Detected radioactive iodine in thyroid	Estimate committed radiation weighted dose to thyroid (go to Procedure F1)

External exposure

In many cases RBE-weighted absorbed dose in organ or tissue T from external exposure, AD_T^{Ext} may be superseded by AD_{Torso}^{Ext} - the RBE-weighted absorbed dose from external exposure averaged over torso of the human body, [Gy-Eq]. Its value may be determined from results of individual monitoring:

$$AD_{Torso}^{Ext} = \theta^{\gamma} \times E_{Ext}^{\gamma} = \theta^{\gamma} \times H_P^{\gamma}(10) \text{ for exposure to photons,}$$

$$AD_{Torso}^{Ext} = \theta^{n} \times E_{Ext}^{n} = \theta^{n} \times H_P^{n}(10) \text{ for exposure to neutrons,}$$

Where:

E_{Ext}^{γ}, E_{Ext}^{n} = effective dose from external exposure to photons or neutrons, [Sv]

$H_P^{\gamma}(10), H_P^{n}(10)$ = personal dose equivalent of external exposure to photons or neutrons as measured by individual dosimeter from dosimeters readings (Worksheet D2), [Sv].

θ^{γ}, θ^{n} = the ratios of the relative RBE for severe deterministic effects to average quality factor $\overline{Q}$ for photons or neutrons respectively:

$\theta^{\gamma} = 1, \frac{Gy - Eq}{Sv}$ for photons and $\theta^{n} = \frac{3}{\overline{Q}^{n}}, \frac{Gy - Eq}{Sv}$ for neutrons.

NOTE

Average quality factor $\overline{Q}^{n}$ for neutrons depends on the neutron spectra and geometry of exposure. For instance, in case of antero-posterio geometry of exposure to unshielded Am/Be or Pu/Be neutron sources $\overline{Q}^{n}$ = 13 Sv/Gy, in case of exposure to unshielded ^{252}Cf source (its spectrum may be used as a surrogate of spectrum in case of criticality emergency) in the same geometry, $\overline{Q}^{n}$ = 16 Sv/Gy.

Combined exposure

In the case of combined internal and external exposure an index of RBE-weighted absorbed doses for intake of radioactive material and for external exposure is to be used for decision making:

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

Where:

$AD(\Delta)_{T,Threshold}$ = listed in Table F2 threshold committed RBE-weighted absorbed dose for developing severe deterministic effect due to internal exposure an organ or tissue *T*

$AD_{T,Threshold}$ = listed in Table F2 threshold committed RBE-weighted absorbed dose for developing severe deterministic effect due to external exposure an organ or tissue *T*.

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

Step 3

For all affected people estimate total effective dose E_{Tot} using formula below:

$$E_{Tot} = E_{Ext} + E_{Inh}(\tau) + E_{Ing}(\tau),$$

Where:

E_{Tot} = total effective dose, [Sv]

E_{Ext} = effective dose from external exposure,[Sv]

$E_{Inh}(\tau)$ = committed effective dose from inhalation, [Sv], (from Step 2 of Procedure F5)

$E_{Ing}(\tau)$ = committed effective dose from ingestion, [Sv], (from Step 2 of Procedure F5)

Estimate the effective dose from external exposure using available information. If data from personal dosimeters are available, use the following equation:

$$E_{Ext} = H_P(10),$$

Where:

E_{Ext} = effective dose from external exposure, [Sv]

$H_P(10)$ = individual dose equivalent as measured by individual dosimeter from dosimeters readings (Worksheet D2), [Sv].

NOTE

Where environmental measurements are available, estimate intake using the methods described in the Section E "Dose assessment" of IAEA-TECDOC 1162 [5] to estimate E_{ext}, E_{Inh} and E_{Ing} If environmental data is not adequate, dose projections may be used (for example, as described in IAEA-TECDOC 955 [3]).

NOTE

If there is need to perform estimation of effective dose of external exposure in case of criticality emergency — use Procedure F4. If there is need to perform estimation of committed effective dose of internal exposure using the results of direct measurements, use Steps 1 and 2 from Procedure F5.

NOTE

In radiation emergency resulting in mass casualties, there could be a need for a quick dose assessment for large number of people seeking reassurance that they will not suffer from the deterministic effects of radiation.

NOTE

Estimation of radiation weighted dose for assessment of probability of occurrence for stochastic effects usually does not represent an urgent task. Usually such data are not needed for immediate medical management of acute effects. However, this is a task for the Health/Medical Physicist. For estimation of radiation weighted dose, see references: [12, 21, 22, 23, 24, 25].

Step 4

Evaluate the results of dose assessment and complete Worksheet F1.

Step 5

Provide Worksheet F1 to medical personnel (physician responsible for treatment or public health officials responsible for registry) to be compared with generic dose criteria in Table F2 for further medical/public health actions.

Purpose

To provide guidance on assessment of dose to thyroid gland.

Discussion

The thyroid gland is a critical organ in emergencies resulting in the release of radioiodine. Information on activity of radioiodine (^{125}I, ^{131}I and ^{133}I) in the thyroid represents the most reliable data for estimation of committed weighted internal dose to the thyroid after the intake of radioiodine. Therefore, prompt action should be taken to perform appropriate measurements and obtain the necessary data for dose assessment.

NOTE

Use Procedure A8b of the IAEA-TECDOC-1092 for guidance on monitoring of thyroid for radioiodine uptake [4].

NOTE

It is recommended to use special equipment calibrated for measuring activity of radioiodine (^{125}I, ^{131}I and ^{133}I) in the thyroid. If this is not possible, use available equipment noting and recording the parameters which characterize the performed measurements. These parameters will be used for *ex post facto* estimation of the calibration coefficients. Examples are: type of equipment, position of equipment while measuring, distance from the neck, use of collimator, etc.

Input

- Data on activity of radioiodine in thyroid measured in ***t*** days after single short-term intake (Worksheets A1, C1, C2 and/or D1);
- Data on isotope composition of the radioiodine released in the emergency (Worksheets A1, C1, C2 and/or D1).

Output

- Results of thyroid dose assessment to the individual (Worksheet F1);
- Recommendation of further actions.

Step 1

Estimate the intake of isotope *Ri* of radioiodine (^{125}I, ^{131}I or ^{133}I) in the thyroid at the time t_0 of single short-term intake using the following formula:

$$I_{Ri}(t_0) = \frac{M_{Thy,Ri}(t)}{f_{Thy,Ri}(g,t)}$$

Where:

$I_{Ri}(t_0)$ = intake of isotope R_i of radioiodine in thyroid at the time t_0 of single short-term intake, [Bq]

t_0 = time moment of single short-term intake, [days]

$M_{Thy,Ri}(t)$ = activity of radioiodine measured in thyroid, [Bq], (from Worksheets C1 and/or D1) at time *t* after intake
$f_{Thy,Ri}(g, t)$ = fraction of intake of radioiodine retained in thyroid of person at age *g,* at time *t* [in days] after intake (thyroid retention function)
g = age of examined person (from Worksheet C2).

NOTE

Data for calculation of $f_{Thy,Ri}(g, t)$ for iodine are presented in Table XII-C6-3. These data are presented in tabulated form for function $f_{Thy,iod}(g, t)$ - fraction of intake of stable iodine retained at time *t* in the thyroid of the person at age *g* (workers and members of the public).
Data for particular isotope of radioiodine may be derived from the data of the corresponding stable element as follows:

$$f_{Thy,Ri}(g,t) = f_{Thy,iod}(g,t) \times \exp(-\lambda_{Ri} \times t),$$

Where:
$f_{Thy,Ri}(g, t)$ = fraction of intake of radioiodine retained in thyroid of person at age *g,* at time *t,* [in days] after intake (thyroid retention function)
$f_{Thy,iod}(g, t)$ = fraction of intake of stable iodine retained in thyroid of person at age *g,* at time *t* [in days] after intake
t = time after intake, days
g = age of person under examination
λ_{Ri} = constant of radioactive decay of isotope of radioiodine R_i, [day^{-1}]. Radioactive decay data for several isotope of radioiodine (^{125}I, ^{131}I and ^{133}I) are presented in Table XII-C6-2.

NOTE

If Worksheets C1 and/or D1 represent the only data on thyroid survey (gamma radiation count rates), it is necessary to estimate the measured activity of radioiodine in thyroid. In a reactor emergency, when a mixture of radionuclides has been released to the environment, it is necessary to measure count rate above neck and thigh (to eliminate input from other radionuclides in the body, e.g., ^{134}Cs or ^{137}Cs in count rate). The following formula is to be used to estimate the measured activity of radioiodine in thyroid:

$$M_{Thy}(t) = (n_n - n_t) \times K,$$

Where
$M_{Thy}(t)$ = the activity retained in thyroid [Bq] at time t_m after intake
n_n = gamma-radiation count rate from the neck [unit of count rate]
n_t = gamma-radiation count rate from the thigh [unit of count rate]
K = calibration coefficient [Bq/unit of count rate].

In an emergency with involvement of radioiodine, use only the following formula to estimate the measured activity of radioiodine in thyroid:

$$M_{Thy}(t) = (n_n - n_b) \times K,$$

Where
$M_{Thy}(t)$= the activity retained in thyroid [Bq] at time t_m after intake
n_n = gamma-radiation count rate from the neck [unit of count rate]
n_b = background gamma-radiation count rate in place of measurement [unit of count rate]
K = calibration coefficient [Bq/unit of count rate].

Step 2

Estimate the committed radiation weighted dose to the thyroid using the formula below:

$$H_{Thy}(\tau) = \sum_{Ri} I_{Ri}(t_o) \times h_{Ri}^{Ing}(g,\tau),$$

Where

$H_{Thy}(\tau)$ = committed radiation weighted dose to thyroid, [Sv]

I_{Ri} = intake of isotope R_i of radioiodine in thyroid at the time $\boldsymbol{t_0}$ of single short-term intake, [Bq]

$h_{Ri}^{Ing}(g,\tau)$ = age-dependent committed radiation weighted dose per unit intake for isotope of radioiodine R_i [Sv/Bq].

NOTE

Data for $h_{Ri}^{Ing}(g,\tau)$ listed in Table XII-D3-3.

NOTE

This scheme is also applicable for estimation of dose in cases of ingestion. As radioiodine activity is measured directly in the thyroid, there is no substantial difference between a thyroid dose assessment based on the ingestion or on the inhalation model.

Purpose

To provide guidance on blood sampling for cytogenetic analysis and on cytogenetic dosimetry.

Discussion

Qualitative/quantitative evaluation of alterations in chromosomes by various techniques such as morphological analysis of metaphase chromosomes, fluorescence *in-situ* hybridization (FISH) and scoring of micronuclei are considered to be useful biological dosimeters of radiation injury. Chromosome aberration analysis in peripheral lymphocytes of individuals exposed to radiation is currently used as a validated method to estimate absorbed dose [26]. The dose is estimated by comparing the observed yields of unstable chromosome aberrations (that is, dicentric and centric rings) with standard dose response curves generated following *in-vitro* irradiation of human lymphocytes. While the technique is normally used for overexposure involving external irradiation, it can also be of value for internal emitters that pervade most body tissues. For example, it has been used to validate doses from intakes of tritiated water that are usually assessed by urinary analysis.

Input

- Information about the patients involved in the emergency (Worksheet A2);
- Medical information form (Worksheet D2).

Output

- Results of cytogenetic analysis (Worksheet F2).

NOTE

Due to the complexity of preparation and scoring of samples, it could be necessary to contact specialized groups outside the country. Assistance could be arranged by the IAEA through ERNET [9]. The Health/Medical Physicist could provide the interface. He/she must ask the cytogenetic laboratory to complete and return Worksheet F2. The sample collection is to be performed by a member of the Radiation Protection Support Group under supervision of the Health/Medical Physicist.

Step 1

Collect 10 ml of peripheral blood in a lithium heparinized vacutainer tube.

NOTE

A venipuncture blood sample for cytogenetic biodosimetry needs to be taken, generally 24 hours after radiation exposure. In cases of severe radiation overexposure (>7 Gy), earlier venipuncture blood sampling is recommended.
If dried heparin is used, it is important that the blood be properly mixed by inverting the tube several times.

Step 2

Label the tubes of blood samples with the name of patient, date and time of collection.

NOTE

In the event of a radiation emergency involving a large number of casualties, perform analysis in accordance with priorities and procedures set up in advance.

Step 3

Place the samples in contact with a coolant pack in an insulated box.

CAUTION

The samples should not freeze.

Step 4

Deliver the samples and copies of the Worksheets A2 and D2 as soon as possible to the cytogenetic laboratory, together with copies of Worksheet F2.

CAUTION

The medical specialist must record the data provided in Worksheet F2 in order to keep a database of necessary information. Delay in obtaining the results from chromosome analysis could make it less suitable as decision criteria for treatment.

Step 5

Process the blood samples in accordance with the protocol [26].

NOTE

The interpretation of dose using a calibration curve produced elsewhere may introduce substantial extra uncertainty. Therefore, any laboratory intending to carry out biological dosimetry needs to establish its own dose-response data.

There is strong evidence that the yield of chromosome aberrations (Y) is related to dose D by the equation $a=A + \alpha D + \beta D^2$. The objective of curve fitting is to determine those values of the coefficients A, α and β which best fit the data points.

NOTE

At the planning stage for the medical response to mass casualty events, the use of cytogenetic dosimetry for early triage of radiation casualties could be considered. For a preliminary estimate of dose to confirm medical triage, only 20 cells need to be scored. In some cases, which mainly involve partial body irradiation, 50 cells may be a more appropriate number to score [27].

Step 6

Make dose estimation using the results of cytogenetic analysis. Evaluate the uncertainty.

Step 7

Complete Worksheet F2 and provide to the Health/Medical Physicist and Hospital Emergency Department Response Team / physician responsible for patient treatment.

Purpose

To provide general guidance on blood sampling and measurement of ^{24}Na in samples of people affected by a criticality emergency.

Discussion

Sodium-24 produced in the patient body by neutron activation is commonly used for the assessment of the neutron dose at a criticality emergency. By theoretical consideration, the specific activity of ^{24}Na in the whole body can be correlated with the fluence of neutrons incident to the body. Though the accurate activity of ^{24}Na in the whole body can be measured by *in-vivo* counting, the amount of stable sodium in the whole body cannot be measured and it differs greatly between individuals. On the other hand, both radioactive and stable sodium can be measured in the blood sample. Since blood is distributed throughout the body, the specific activity in the blood is a good representative of that in the whole body. The gamma spectrometry of ^{24}Na in the blood sample does not need any chemical processing or an expensive facility, in contrast to *in-vivo* counting.

Input

- Information about patients involved in the emergency (Worksheet A2);
- Information for neutron dose assessment for criticality emergency (Worksheet F3).

Output

- Results of measurement of ^{24}Na concentration in blood samples (Worksheet F4).

Equipment/Supplies

- NaI (Tl) scintillation or Ge semiconductor spectrometer with appropriate shielding;
- Sample containers;
- Standard sources.

Step 1

Collect a blood sample from the patient (10 to 20 cm^3) as soon as possible after exposure.

NOTE

Intravenous administration given to patients as initial treatment may dilute the concentration of ^{24}Na in the blood or accelerate its excretion. Both will lead to underestimation of the specific activity of ^{24}Na.

Step 2

Transfer the blood sample from the syringe to a container for gamma-ray measurement, e.g. polystyrene U8 cylindrical container, and add a small amount of heparin to prevent blood coagulation. Shake container.

NOTE

When solvent has to be added to redissolve the blood sample, the amount needs to be measured accurately, because solvents usually contain stable sodium to some extent, which will introduce an error to the measurement of specific activity.

Step 3

Check the energy (and efficiency) calibration of the gamma-ray spectrometer using standard sources under the same counting geometry as for the sample measurement.

NOTE

IAEA-TECDOC-1092 [4] will be helpful for generic procedures for gamma spectrometry.

Step 4

Put the container into a predetermined position of the measurement system and start data acquisition.

Step 5

Calculate the fraction of ^{24}Na retained in the blood at the time of sample collection, using the equation below:

$$R(t_s) \approx (1-\alpha(t_s)) \times \exp(-\lambda \times t_s),$$

Where

t_s = time of sample collection

$R(t_s)$ = fraction of ^{24}Na retained in the blood at the time t_s of sample collection

$\alpha(t_s)$ = fraction of ^{24}Na eliminated from blood till the time of sample collection t_s due to excretion of sodium from the body (e.g. due to excretion with urine). Default value for $\alpha(t_s)$ is equal to 0

λ = decay constant of ^{24}Na (1.28×10^{-5} s^{-1}).

Step 6

Calculate the activity of ^{24}Na at the time of exposure to neutrons using the equation below [28]:

$$A_0 = \frac{\lambda}{\left(e^{-\lambda t_1} - e^{-\lambda t_2}\right)} \times \frac{C_{net}}{R(t_s) \times \varepsilon_f},$$

Where

A_0 = activity of ^{24}Na in the sample at the time of exposure to neutrons [Bq]

t_1 = elapsed time between the time of sample collection and the start of counting

t_2 = elapsed time between the time of sample collection and the end of counting

λ = disintegration constant of ^{24}Na (1.28×10^{-5} s^{-1})

C_{net} = net counts of ^{24}Na between t_1 and t_2 corrected for background counts

ε_f = counting efficiency of the detector

$R(t_s)$ = the fraction of ^{24}Na retained in the blood at the time t of sample collection.

Step 7

Calculate the concentration a_0 of ^{24}Na in the blood of patient for the time of exposure to neutrons:

$$a_0 = A_0 / v ,$$

Where

a_0 = concentration of ^{24}Na in the blood sample for the time of exposure to neutrons [Bq×cm^3]

A_0 = activity of ^{24}Na in the sample at the time of exposure to neutrons obtained in Step 6 [Bq]

v = volume of blood sample, collected from the patient, [cm^3].

Step 8

Complete Worksheet F4 and deliver it to the requested group of specialists.

Step 9

Record all the actions in logbook.

Purpose

To provide general guidance on neutron dose assessment for people affected by criticality emergency.

Discussion

Neutron dose at a criticality emergency greatly depends on the fluence of the incident neutrons and on the energy spectrum of neutrons incident to the human body. The neutron spectrum in turn differs depending on the criticality system and the surrounding materials. Therefore, dose assessment specific to the emergency is usually required.

Neutrons released at a criticality emergency activate various materials surrounding the criticality system. The human body is also subject to the activation, which produces various radionuclides such as ^{24}Na, ^{31}P, ^{39,41}K or ^{44}Ca in the body of the patients. Among them, ^{24}Na ($T_{1/2}$ = 14.96 h) is commonly used for the assessment of the neutron dose, because it is generated from stable sodium, which is distributed almost uniformly throughout the body, and because it emits high energy gamma-rays, which are easily detected. Theoretical correlation of the radioactivity in the blood sample with the neutron fluence incident enables neutron dose assessment for emergency medical preparedness.

Experience has shown that neutron exposure in emergency conditions usually occurs for personnel or emergency workers. In some cases, such exposure leads to deterministic health effects. Therefore, practical steps on calculation of RBE-weighted absorbed dose from neutron exposure are presented in this procedure.

Input

- Information about the patients involved in the emergency (Worksheet A2);
- Information for neutron dose assessment for criticality emergency (Worksheet F3);
- Results of measurement of ^{24}Na concentration in the blood samples (Worksheet F4).

Output

- Results of neutron dose assessment (Worksheet F5).

Step 1

Calculate the specific activity of ^{24}Na in the blood at the time of exposure using the formula below:

$$\alpha_0 = a_0 / \rho_{Na} ,$$

Where

α_0 = generated specific activity ^{24}Na in the blood of patient [Bq $_{Na-24}$ / g_{Na}]

a_0 = concentration of ^{24}Na in the blood of patient for the time of exposure to neutrons [Bq×cm^3] (from Step 7 Procedure F3)

ρ_{Na} = concentration of stable sodium in the blood [g_{Na}×cm^3]; the default value of ρ_{Na} is 1.9×10^{-2} g_{Na}×cm^{-3} [29].

NOTE

For example, the concentration of stable sodium in the blood can be determined accurately using inductively coupled plasma atomic emission spectrometry (ICP-AES). If it is impossible to measure the concentration of stable sodium, the default value is to be used.

Step 2

Estimate the neutron spectrum.

NOTE

For example, a computer code ANISN (multigroup one-dimensional discrete ordinates transport code system with anisotropic scattering) [30] may be used for the estimation of the neutron spectrum. If it is impossible to estimate the neutron spectrum by computational simulation, the spectrum data listed in the IAEA Technical Report Series No 180 [31] and No 318 [32] may be used.

Step 3

Calculate the fluence of the incident neutrons from the neutron spectrum and the specific activity of ^{24}Na in the blood of patient generated in time of exposure to neutrons, α_0, using the equation below [33]:

$$\Phi = \frac{V \times A_{Na} \times \Sigma_{th}}{\lambda \times \sigma \times N_{av} \times S \times \xi\{\phi(E_n)\}} \times \alpha_0 ,$$

Where

α_0 = generated specific activity [Bq $_{\text{Na-24}}$ / g$_{\text{Na}}$]

V = volume of human body (the default value of V is 68280 cm^3) [34]

S = projected area of human body (the default value of S is 5690 cm^2) [34]

Φ = fluence of the incident neutrons [cm^{-2}]

λ = decay constant of ^{24}Na (1.28×10^{-5} s^{-1})

σ = absorption cross section of ^{23}Na for thermal neutrons (5.34×10^{-25} cm^2) [35]

Σ_{th} = macroscopic total absorption cross section of human body for thermal neutrons (0.02339 cm^{-1}) [28]

N_{av} = Avogadro's number (6.03×10^{23} mol^{-1})

A_{Na} = mass of stable sodium per mol (23 g/mol)

$\xi\{\phi(E_n)\}$ = capture probability of human body for neutrons with fluence per unit energy $\varphi(E_n)$.

For fission neutrons $\xi\{\text{fission}\}$ = 0.254 [34].

For any other neutron spectra, it may be calculated using the formula below:

$$\xi\{\phi(E_n)\} = \left(\frac{\int_0^\infty \xi(E_n)\phi(E_n)dE_n}{\int_0^\infty \phi(E_n)dE_n} \right),$$

Where

$\varphi(E_n)$ = neutron fluence per unit energy [cm^{-2}×eV^{-1}]

$\xi(E_n)$ = capture probability of human body for neutrons of the energy E_n, [34]:

En, MeV	Capture	En, MeV	Capture	En, MeV	Capture	En, MeV	Capture
1E-09	0.181	0.01	0.299	0.794	0.300	3.50	0.206
1E-06	0.305	0.100	0.302	1.00	0.249	4.50	0.197
1E-05	0.348	0.300	0.309	1.26	0.273	6.31	0.156
1E-04	0.345	0.440	0.258	2.00	0.253	10	0.147
1E-03	0.320	0.501	0.305	2.51	0.242	14.1	0.133

NOTE

Useful recommendations for calculation integrals containing neutron spectrums (functions of neutron fluence per unit energy) may be found in the IAEA Technical Report Series No 318 [32].

Step 4

Calculate the absorbed dose d_T for the organ T per unit fluence of the neutrons, using the equation below:

$$d_T = \frac{\int_0^\infty d_T\left(E_n\right)\phi\left(E_n\right)dE_n}{\int_0^\infty \phi\left(E_n\right)dE_n},$$

Where

d_T = absorbed dose for the organ T per unit fluence of the neutrons with the energy spectrum $\varphi(E)$, [pGy×cm^2]

$\varphi(E_n)$ = neutron fluence per unit energy [cm^{-2}×eV^{-1}]

$d_T(E_n)$ = absorbed dose for the organ T per unit fluence of the neutrons with the energy E_n, [pGy×cm^2].

NOTE

The value from tables A.26 - A.40 of ICRP Publication 74 [24] is to be used as $d_T(E_n)$ [pGy×cm^2] for red marrow, colon, stomach as a surrogate of wall of small intestine, lung, bone surface, liver, thyroid.

Step 5

Calculate the absorbed dose in the organ T from the neutrons corresponding to the measured specific activity of ^{24}Na in the blood, using the equation below:

$$D_T^{Ext,n} = 1\times 10^{-12}\times d_T\times\Phi,$$

Where

$D_T^{Ext,n}$ = absorbed dose in the organ T from the neutrons with the energy spectrum $\varphi(E)$ and fluence Φ, [Gy]

d_T = absorbed dose for the organ T per unit fluence of the neutrons with the energy spectrum $\varphi(E)$, [pGy×cm^2]

Φ = fluence of the incident neutrons [cm^{-2}]

1×10^{-12}= conversion coefficient from pGy to Gy.

Step 6

Calculate the RBE-weighted absorbed dose AD_T in the organ T of the neutrons, using the equation below:

$$AD_T^{Ext,n} = D_T^{Ext,n} \times RBE^n ,$$

Where

$AD_T^{Ext,n}$ = RBE-weighted absorbed dose in the organ T from the neutrons with the energy spectrum $\varphi(E)$ and fluence Φ, [Gy-Eq]

$D_T^{Ext,n}$ = absorbed dose in the organ T from the neutrons with the energy spectrum $\varphi(E)$ and fluence Φ, [Gy]

RBE^n = relative biological effectiveness of neutrons for severe deterministic effects. The default value of RBE^n is 3 Gy.

NOTE

In addition to neutrons, photons are emitted from nuclear fission (prompt gamma-rays). Moreover, high energy photons (2.2 MeV) are emitted at the process whereby neutrons are captured by hydrogen nuclei in the criticality system and surrounding material (capture gamma-rays). The absorbed dose by the photons at previously occurring criticality emergencies has sometimes been larger than that of neutrons [33]. As to the Tokai-mura emergency, photon absorbed dose might reach 1.4- to 1.9-fold of that of neutrons [36]. On the other hand, the photon absorbed dose in the Sarov emergency was not more than 10% of neutron absorbed dose [37]. Since high energy photons are less attenuated in the body than neutrons, the photon dose may become dominant in the deep organs. The assessment of photon dose is usually difficult. The value of the neutron to gamma-ray kerma ratios in IAEA Technical Reports Series No. 211 [33] may be helpful for the estimation of photon dose. In general, the cytogenetic technique is used for photon dose assessment in a criticality emergency as described in Procedure F2. An example of such an approach may be found in the IAEA report on Sarov emergency [37].

Step 7

Complete Worksheet F5 and deliver it together with Worksheet F3 to the medical specialist responsible for patient treatment.

CAUTION

Be sure that the photon dose due to the criticality emergency has been estimated. If not, draw the attention of the medical specialist responsible for patient treatment to this fact.

Step 8

Record all actions in logbook.

Purpose

To provide a general guidance to evaluate the intake and to estimate the:

- committed effective dose based on bioassay measurements;
- RBE-weighted absorbed dose delivered to organ or tissue of the individual over definite time after acute intake of radionuclides, on the basis of bioassay measurements;
- committed RBE-weighted absorbed doses to the embryo and foetus, on the basis of bioassay measurements.

Discussion

In a radiation emergency, an individual may be exposed through various pathways. External exposure may be a consequence of direct irradiation from the source, from airborne radionuclides, or from the radionuclides deposited onto the ground and onto clothing and skin. Internal exposure follows the inhalation and ingestion of radioactive material or absorption through contaminated skin and wounds. Intake of radionuclides can be determined by *in-vitro in-vivo* bioassay techniques. The early estimation of intake from bioassay measurements and the assessment of effective committed dose are often requested by emergency medical personnel in order to determine if the internal exposure is high enough to justify decorporation therapies and, also, to follow-up the treatment. Both *in-vivo* and *in-vitro* monitoring programme needs to be conducted at suitable intervals for an extended period after an accidental intake. Values of committed effective dose could be used for the assessment of radiation detriment and planning of long term protective action for radiation protection of the population (e.g. for zoning of territories, protective measures in agriculture). Results of assessment of RBE-weighted absorbed dose could be used for evaluation and medical management of the deterministic health effects.

Input

- Information for internal dose assessment (Worksheet F6);
- Results of *in-vitro* bioassay measurements (Worksheet F9);
- Results of *in-vivo* bioassay measurements (Worksheet F11).

Output

- Results of internal dose assessment (Worksheet F7).

NOTE

If a hospital has no expertise to conduct the assessment of intake and the estimation of committed effective and RBE-weighted absorbed doses, then it needs to contact groups of specialists in the country or internationally. The IAEA could arrange assistance in this respect [9]. Information on the procedure to follow in order to get such assistance in an emergency needs to be known in the hospital in advance. In such cases, the hospital Health/Medical Physicist could provide the interface. He/she needs to ask the expert group to complete and return Worksheets F7, F9 and F11 after measurement.

NOTE

If the hospital has its own established methodology and trained staff to perform the evaluation of internal dose, then skip steps 1 and 2. The next steps could be performed using the results from *in-vitro* (Worksheet F9) and *in-vivo* (Worksheet F11) bioassay.

Step 1

Estimate the intake *I* using the following formula:

$$I_R = \frac{M_{T,R}(t)}{f_{T,R}(g,t)},$$

Where:

I_R = intake of radionuclide *R* [Bq]

t = time after intake [days]

$M_{T,R}(t)$ = activity of radionuclide *R* returned in organ *T* [Bq] (from Worksheet F11) or the activity in daily excreta [Bq/day] (from Worksheet F9) at time *t* after intake

$f_{T,R}(g\ t)$ = fraction of the intake of radionuclide *R* retained in the whole body or in a specific organ *T* of the person at age *g*, or excreted from the body in 24 hours at time *t* [in days] after intake (retention or excretion function respectively)

NOTE

Index *T* means the organ where activity was retained and measured by means of Procedure F7 or excreta (urine or faeces) with what activity was excreted and measured by means of Procedure F6.

NOTE

Data for calculation of $f_{T,R}(g,\ t)$ for selected elements (hydrogen, iron, cobalt, strontium, ruthenium, iodine, caesium, radium, thorium, uranium, neptunium, plutonium, americium, curium, californium) are presented in Appendix XII. In cases of inhalation by members of the public and workers, see data from Tables XII-A1 – XII–A16-4, in cases of ingestion, data from Tables XII-C1-1 – XII-C15-4). These data are presented in tabulated form for function $f_{T,[R]}(g,\ t)$ - fraction of intake of stable elements *[R]* retained in the whole body or in a specific organ *T* of the person at age *g*, or excreted from the body in 24 hours at time *t* [in days] after intake (retention or excretion function respectively).

Data for particular radionuclides may be derived from the data of the corresponding stable element as follows:

$$f_{T,R}(g,t) = f_{T,[R]}(g,t) \times \exp(-\lambda_R \times t),$$

Where:

$f_{T,R}(g,t)$ = the fraction of the intake of radionuclide *R* retained in the whole body or in a specific organ *T* of the person at age *g*, or excreted from the body in 24 hours at time *t* [in days] after intake (retention or excretion function respectively)

$f_{T,[R]}(g,t)$ = fraction of intake of stable element *[R]* retained in the whole body or in a specific organ *T* of the person at age *g*, or excreted from the body in 24 hours at time *t* [in days] after intake (retention or excretion function respectively)

t = time after intake, days

g = age of person under examination

λ_R = constant of radioactive decay of radionuclide R, day^{-1}. Radioactive decay data for several radionuclides of interest is presented in Appendix XII.

NOTE

Generic values of $f_{T,R}(g, t)$ for selected radionuclides in whole-body, certain organs or excreta for workers may be found in the ref. [12, 38]. For workers and members of the public, a database on an Internet web site: **http://www.nirs.go.jp:8080/anzendb/RPD/gpmd.php** may provide a source for the values of $f_{T,R}(g, t)$. This database may also help health/medical physicists to estimate intake of radionuclides, in the case that the particle size is not 5 μm.

Step 2

Assess the committed effective dose after intake (inhalation or ingestion) using the following formula:

$$E_{Inh}(\tau) = I_{Inh} \times e^{Inh}(g,\tau),$$
$$E_{Ing}(\tau) = I_{Ing} \times e^{Ing}(g,\tau),$$

Where:

$E_{Inh}(\tau)$ = committed effective dose from inhalation [Sv]
$E_{Ing}(\tau)$ = committed effective dose from ingestion [Sv]
I_{Ing} = intake from ingestion, estimated in Step 1 [Bq]
I_{Inh} = intake from inhalation, estimated in Step 1 [Bq]
$e^{Inh}(g,\tau)$ = dose coefficient (committed effective dose per unit intake) for the given radionuclide and exposed group (members of the public with age g or workers) through inhalation [Sv×Bq^{-1}]
$e^{Ing}(g,\tau)$ = dose coefficient (committed effective dose per unit intake) for the given radionuclide and exposed group (members of the public with age g or workers) through ingestion [Sv×Bq^{-1}]

NOTE

Dose coefficients are available in Tables XII-B1-1 and XII-B1-2 of Appendix XII for inhalation and in Tables XII-D1-1 and XII-D1-2 of Appendix XII - for ingestion of the following radionuclides: ^{3}H; ^{59}Fe; ^{57}Co, ^{58}Co, ^{60}Co; ^{85}Sr, ^{89}Sr, ^{90}Sr; ^{106}Ru; ^{125}I, ^{131}I, ^{133}I; ^{134}Cs, ^{137}Cs; ^{226}Ra, ^{228}Ra; ^{228}Th, ^{232}Th; ^{234}U, ^{235}U, ^{238}U; ^{237}Np; ^{238}Pu, ^{239}Pu, ^{240}Pu; ^{241}Am; ^{242}Cm, ^{244}Cm; ^{252}Cf.

NOTE

Dose coefficients $e(g)$ are available in the ref. [39]. The values are for specific routes of intake and cannot be used directly for assessment of doses due to entrance into the blood through the wound or absorption through the skin.

Step 3

Assess the RBE-weighted absorbed dose delivered to organ or tissue T over definite time Δ after intake (inhalation or ingestion) using the following formula:

$$AD_T^{Inh}(\Delta) = I_{Inh} \times Ad_T^{Inh}(g,\Delta),$$
$$AD_T^{Ing}(\Delta) = I_{Ing} \times Ad_T^{Ing}(g,\Delta),$$

Where:

$AD_T^{Inh}(\Delta)$ = committed RBE-weighted absorbed dose delivered to organ or tissue T over definite time t after accidental inhalation [Gy-Eq]

$AD_T^{Ing}(\Delta)$ = committed RBE-weighted absorbed dose delivered to organ or tissue *T* over definite time *t* after accidental ingestion [Gy-Eq]

I_{Ing} = intake from ingestion, estimated in Step 1 [Bq]

I_{Inh} = intake from inhalation, estimated in Step 1 [Bq]

$Ad_T^{Inh}(g,\Delta)$ = dose coefficient (committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue *T* of members of the public with age *g* or workers over definite time Δ after acute inhalation of specific radionuclide) [Gy-Eq×Bq^{-1}]

$Ad_T^{Ing}(g,\Delta)$ = dose coefficient (committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue *T* of members of the public with age *g* or workers over definite time Δ after acute ingestion of specific radionuclide) [Gy-Eq×Bq^{-1}].

NOTE

Dose coefficients are available in Tables XII-B2-2 and XII-B3-1 of Appendix XII for inhalation and in Tables XII-D2-2 and XII-D3-1 of Appendix XII - for ingestion of the following radionuclides: ^{3}H; ^{59}Fe; ^{57}Co, ^{58}Co, ^{60}Co; ^{85}Sr, ^{89}Sr, ^{90}Sr; ^{106}Ru; ^{125}I, ^{131}I, ^{133}I; ^{134}Cs, ^{137}Cs; ^{226}Ra, ^{228}Ra; ^{228}Th, ^{232}Th; ^{234}U, ^{235}U, ^{238}U; ^{237}Np; ^{238}Pu, ^{239}Pu, ^{240}Pu; ^{241}Am; ^{242}Cm, ^{244}Cm.

Step 4

In a case of internal accidental exposure of a possible pregnant female worker, assess the committed RBE-weighted absorbed dose to the offspring per unit intake of female worker using the following formula:

$$AD_{Offspring}^{Inh}(\Delta) = I_{Inh} \times Ad_{W,offspring}^{Inh}(\Delta),$$

$$AD_{Offspring}^{Ing}(\Delta) = I_{Ing} \times Ad_{W,offspring}^{Ing}(\Delta),$$

Where:

$AD_{Offspring}^{Inh}(\Delta)$ =committed RBE-weighted absorbed dose to the offspring per unit intake of female worker after accidental inhalation [Gy-Eq]

$AD_{Offspring}^{Ing}(\Delta)$ =committed RBE-weighted absorbed dose to the offspring per unit intake of female worker after accidental ingestion [Gy-Eq]

I_{Ing} =intake from ingestion, estimated in Step 1 [Bq]

I_{Inh} =intake from inhalation, estimated in Step 1 [Bq]

$Ad_{W,offspring}^{Inh}(\Delta)$ = dose coefficient (committed RBE-weighted absorbed dose to the offspring per unit intake of female worker) for the specific radionuclide through inhalation [Gy-Eq×Bq^{-1}]

$Ad_{W,offspring}^{Ing}(\Delta)$ = dose coefficient (committed RBE-weighted absorbed dose to the offspring per unit intake of female worker) for the specific radionuclide through ingestion [Gy-Eq×Bq^{-1}].

NOTE

Dose coefficients are available in Table XII-B2-1 for inhalation and in Table XII-D2-1 of Appendix XII - for ingestion of the following radionuclides: ^{3}H; ^{59}Fe; ^{57}Co, ^{58}Co, ^{60}Co; ^{89}Sr, ^{90}Sr; ^{106}Ru; ^{125}I, ^{131}I, ^{133}I; ^{134}Cs, ^{137}Cs; ^{226}Ra, ^{228}Ra; ^{228}Th, ^{232}Th; ^{234}U, ^{235}U, ^{238}U; ^{237}Np; ^{238}Pu, ^{239}Pu, ^{240}Pu; ^{241}Am; ^{242}Cm, ^{244}Cm.

Step 5

Complete Worksheets F6 and F7 and deliver them to the medical specialist responsible for patient's treatment.

CAUTION

The Step 6 is to be performed if a group of specialists perform the evaluation of internal dose.

Step 6

Deliver copies of completed Worksheets F6 and F7 to the requested group of specialists. Instruct the group of specialists to return completed Worksheet F7.

Step 7

Complete the final result of internal contamination assessment (Worksheet F7) at the end of a series of the measurements decided by health/medical physicists and medical specialists.

NOTE

When the estimated values of intake are highly dispersed, the data need to be treated carefully under consideration with the uncertainty of each datum. If the trend of the values *M* differs much from that of *f(t),* dose estimation specific to the patient is required.

Step 8

Record all actions in logbook.

NOTE

The medical specialist must record the data provided in Worksheet F7 in order to keep a database of necessary information.

Purpose

To provide guidance on management of *in-vitro* bioassay measurements.

Discussion

In-vitro bioassay is the determination of radionuclide concentrations in excreta samples and other biological materials, such as hair, nasal and mouth swabs, excised tissue and breath. In order to obtain correct results of assessment, sampling needs to be properly performed.

CAUTION

Samples should be collected when the patients' medical condition permits.

Input

- Information about the patients involved in the emergency (Worksheet A2);
- Results of radiological survey of patients (Worksheet D1);
- Data on decorporation follow-up (Worksheet D4);
- Information for internal dose assessment (Worksheet F6);
- Information for *in-vitro* bioassay laboratory (Worksheet F8).

Output

- Representative biological samples;
- Results of *in-vitro* bioassay measurements (Worksheet F9) if the hospital has its own *in-vitro* bioassay laboratory.

NOTE

If a hospital has no expertise and equipment to perform *in-vitro* bioassay measurements, it should contact specialized laboratories. The IAEA could arrange assistance in this respect [9]. Information on the procedure to follow in order to get such assistance in an emergency needs to be known in the hospital in advance. In such cases the hospital Health/Medical Physicist could provide the interface. He/she must ask the specialized laboratory to complete and return Worksheet F9.

PRECAUTION

Standard radiation protection procedures must be followed when performing biological sampling and when dealing with contaminated patients. Sampling may be handled by a member of the Radiation Protection Support Group under supervision of the Health/Medical Physicist.

Urine and Faeces Samples

2.5.17.3.1

2.5.17.3.2 NOTE

Excreta measurement data is a reliable indicator of actual internal contamination for many radionuclides. The choice between urine or faeces samples will depend upon the major route of excretion, which depends on the intake pathway, on the solubility of the radioactive compound, on the biokinetic of the radionuclide and also on the Ease of sample collection, analysis and interpretation.

Fast screening of patients suspected to have had significant intake of radionuclides emitting high-energy photons could be performed in an appropriate location of the hospital using transportable counting equipment.

If the contaminant is an alpha emitter, an extensive radiochemical procedure may be required, followed by spectroscopy methods, requiring thus a long time to have a quantitative response. Some non-radiometric methods may also be used, but still do not supply immediate response (approximately one day). Methods for analysis of some selected radionuclides are presented in Table F4 [25].

TABLE F4. METHOD OF ANALYSIS FOR SELECTED RADIONUCLIDES

Radionuclide	Sample	Method
H-3, C-14, Sr-89, 90,P-32	urine	liquid scintillation
Fe-59	urine	gamma-spectrometry
Co-57, 58, 60	urine, faeces	gamma-spectrometry
Sr-85, 89, 90	urine	liquid scintillation
Ru-106	urine	gamma-spectrometry
I-125, 129, 131	urine	gamma-spectrometry, liquid scintillation
Cs-134, 137	urine	gamma-spectrometry
Ra-226, 228 and Pb-210	urine	proportional counter
Uranium	urine	fluorimetry, alpha spectrometry, inductively coupled plasma mass spectrometry (ICP-MS)
Thorium	urine, faeces	spectrophotometry, alpha spectrometry, ICP-MS
Pu-238, 239, 240	urine, faeces	alpha spectrometry
Np-227	urine, faeces	gamma-spectrometry
Am-241	urine, faeces	alpha spectrometry
Cm-242, 244	urine, faeces	alpha spectrometry
Cf-252	urine, faeces	gamma-spectrometry, alpha spectrometry
Fission and activation products	urine, faeces	gamma spectrometry

NOTE

Daily excretion (24 hour samples) should be collected for analysis. Follow-up measurements of daily excretion are recommended. An exception is the monitoring of the intake of tritiated water, when sequential sampling, instead of 24-hour sampling is preferred.

Where 24 hour samples are not easily collected, the first morning voiding is preferable for analysis [40]. The daily excretion of creatinine, produced as a metabolic product in muscle metabolism, is typically less variable than the volume of fluid loss in urine. Measurements of creatinine levels in urine have therefore been used to estimate 24 hour excretion of radionuclides from urine samples collected over part of a day. The method for determination of creatinine in urine samples is given in IAEA Safety Reports Series No.18 [13].

CAUTION

When decorporation treatment is adopted, the route of excretion following the treatment should be taken into account.

Step 1

Start with the excreta sample collection from patients suspected to be internally contaminated. Collect samples in plastic bottles or appropriate containers and handle with care to avoid cross-contamination.

CAUTION

Avoid collecting samples in a contaminated area.

Step 2

Label the sample containers with:

- patient name
- sampling date and time
- dose rate at the surface of the container (if the radionuclide is a gamma emitter).

Step 3

Pack the containers in plastic bags, seal and keep them cool or frozen until analysis.

NOTE

If the hospital has its own *in-vitro* bioassay laboratory, Step 4 is to be followed.

Step 4

Perform measurements, complete Worksheet F9 and deliver it to the medical specialist responsible for the patient's treatment.

NOTE

Step 5 is to be followed if an outside specialized laboratory performs the *in-vitro* bioassay measurements.

Step 5

Complete Worksheet F7. Deliver samples together with the copies of Worksheets F7 and F9 to the designated *in-vitro* bioassay laboratory. Instruct the *in-vitro* laboratory personnel to return completed Worksheet F9.

Step 6

Record all the actions in logbook.

CAUTION

The medical specialist must register the data provided in Worksheet F9 in order to keep a database of necessary information.

Other Biological Samples

NOTE

The above steps are also valid for other biological samples (hair or nasal swabs) analyzed by bioassay techniques. The results are only qualitative and it is not possible to evaluate the internal dose on the basis of such types of samples.

In cases of inhalation of radionuclides, a nasal swab should be applied to determine which radionuclides are involved. Nasal samples must be taken as soon as the potential exposure is noted. Sampling should be implemented quickly due to the rapid clearance of particles from the anterior nasal passages. Though the interpretation of the measurement results on nasal samples is affected by a number of conditions, physicians may have to begin treatment before the internal dose is evaluated. In a case of plutonium inhalation, a value greater than 500 dis/min indicates a possible serious exposure [41].

Mouth swabs and collection of vomited material may help to assess contamination by ingestion. A contaminated wound may require debridment, which can be used to check the depth of contamination and the effectiveness of decontamination treatment. The results cannot be applied to internal dose assessment.

CAUTION

Measurements of radionuclide concentrations in blood cannot be used to assess intake. These results provide limited information on systemic activity, since clearance from blood to tissues is very fast and interpretation of results is not simple.

NOTE

Biodosimetry techniques such as cytogenetic analysis (chromosome aberrations, micronuclei analysis, FISH) are normally used for overexposure involving external irradiation. In addition, it may also be used for a qualitative evaluation of internal contamination. In a case of contamination by tritiated water and inhalation of tritium gas, or by other internal emitters that pervade most body tissues, a quantitative evaluation through chromosome aberration analysis is possible (Procedure F2). However, the delay involved in obtaining the results makes it less suitable as criteria for treatment than urine analysis.

Purpose

To provide guidance on management of *in-vivo* bioassay measurements.

Discussion

In-vivo bioassay measurement provides the most rapid and reliable data for the estimation of the total activity of radionuclides in the whole body or in a specific region of the body at the time of measurement. Whole body counters (fixed or transportable) and special counters such as low energy chest counters, wound monitors, thyroid counters, or screening equipment could be used to perform these measurements. In some cases, medical devices such as gamma cameras can also be calibrated for quantification of activity in the body. Detailed instructions on performing measurements with the use of whole body counters could be found in [42, 43, 44].

Proposed counting geometry for selected radionuclides is presented in Table F5, where two crosses mark the most probable localization of radionuclide in the body and one cross marks the possible, but rare localization.

TABLE F5. COUNTING GEOMETRY FOR SELECTED RADIONUCLIDES

Radionuclide	Geometry		
	whole body	lung	thyroid
Fission/activation products	+	++	+
Fe-59	+	++	
Co-57		++	
Co-58		++	
Co-60		++	
Sr-85	++	+	
Ru-106	+	++	
I-125, 129, 131		+	++
Cs-134, 137	++	+	
Ra-226, 228		++	
U-235	+	++	
Th-228, 232		++	
Np-237		++	
Am-241		++	
Cf-252		++	

Input

- Information about emergency victims (Worksheet A2);
- Results of radiological survey of the patients (Worksheet D1);
- Data on decorporation follow-up (Worksheet D4);
- Information for internal dose assessment (Worksheet F6);
- Information for *in-vivo* bioassay laboratory (Worksheet F10).

Output

- Results of *in-vivo* bioassay measurements (Worksheet F11).

NOTE

If a hospital has no expertise or equipment to conduct in-vivo bioassay measurements, it should contact specialized laboratories. The IAEA can provide assistance in this respect [9]. In such cases the hospital Health/Medical Physicist could provide the interface. He/she must ask the bioassay laboratory to complete and return Worksheet F11.

PRECAUTION

The bioassay laboratory must have the capability for dealing with highly contaminated individuals. Standard radiation protection procedures must be followed when dealing with the patients.

If patients are externally contaminated, measurement is not recommended while external contamination persists, since an overestimation of body burden may occur. Alternatively, the externally contaminated region may be shielded during the *in-vivo* count. If transportable *in-vivo* counting equipment is available, measurement can be performed at or near the hospital. It is a useful tool in cases of patients clinically incapacitated due to acute radiation exposure. If the intake is extremely high, special geometry arrangements of the detectors may be required to avoid problems with equipment response, such as dead time. If possible, *in-vivo* measurements should be carried out at regular intervals to determine the clearance of the material from the body.

Step 1

Decontaminate the patient, if applicable, before body monitoring is undertaken. Use Procedure D2 if necessary.

Step 2

Explain the measurement procedures to the patient.

Step 3

Supervise the transfer of the patient to the whole body counting facility.

NOTE

If the hospital has its own *in-vivo* bioassay laboratory, Step 4 is to be followed.

Step 4

Perform measurement, complete Worksheet F11 and deliver it to the medical specialist responsible for patient's treatment.

NOTE

Step 5 is to be followed if an outside specialized laboratory performs the *in-vivo* bioassay measurement.

Step 5

Deliver a copy of completed Worksheet F11 to the whole body counting facility, along with copies of Worksheet F10. Ask the *in-vivo* bioassay laboratory to complete and return Worksheet F11.

Step 6

Record all actions in logbook.

CAUTION

The medical specialist must register the data provided in Worksheet F11 in order to keep a database of necessary information.

SECTION G
PUBLIC HEALTH RESPONSE

Caution: *The procedures in this section should be adapted to reflect national, local and hospital conditions and capabilities for which they will be applied.*

Performed by:	**PROCEDURE G1**	
Public Health Advisor	**IMMEDIATE PUBLIC HEALTH RESPONSE: STABLE IODINE PROPHYLAXIS**	*Page 1 of 2*

Purpose
To provide guidance on how to initiate administration of stable iodine for the purpose of thyroid blocking in case of radiation emergency.

Discussion
The main part of the thyroid dose is formed due to absorption of radioiodine by the thyroid gland. As a result of nuclear power plant emergencies, a release of large quantities of various radioisotopes of iodine may occur. Thus, the potential for large doses to the thyroid exists. These doses could be prevented by blocking the thyroid gland with stable iodine. Stable iodine should be used only in the case of an emergency with release of radioactive iodine.
Depending on the emergency arrangements in a country and the scale of the emergency, public health officials may have to advise decision makers or decide themselves on the administration of the stable iodine. Established in advance criteria shodul be used for decision making (see Appendix II for details).

Input
- Notification to the Public Health Advisor by the Medical Response Initiator of a real or potential radiation emergency situation with threat to public health.

Output
- Decision on need for initiation of stable iodine prophylaxis.

Step 1
Obtain from the Accident Assessment Manager [3] or another authorized person all relevant information as to the nature of the emergency, including:

- Emergency site;
- The classification of the emergency (General emergency/Site Area emergency/Alert), if occurred at NPP ;
- Release of contaminated material;
- Presence of radioactive iodine in released material;
- Meteorological conditions;
- Size of population at risk within each of the planning zones;
- Presence of sensitive or unusual populations in area affected (e.g. schools, hospitals);
- Probability of evolution of event (completed/continuing/escalating).

Step 2
In case of General emergency at NPP iInstruct public in precautionary action zone (PAZ) and urgent protective action planning zone (UPZ) to take pre-distributed stable iodine pills (if pre-distribution was made) [6].

Step 3

In case of General emergency at NPP, if pre-distribution of stable iodine pills within the PAZ and the UPZ has not been carried out, immediately activate the distribution plan.

Step 4

Notify public about the beginning of stable iodine prophylaxis and methods of its implementation.

NOTE

Experience of response has shown that it could be practical to have pre-distribution of stable iodine pills within the vicinity of an NPP (territory of PAZ and UPZ). However, implementation of stable iodine prophylaxis outside the territory of PAZ and UPZ could be also warranted. A plan of stable iodine distribution should be prepared in advance at the stage of preparedness to public health response in radiation emergencies. This plan has to contain information on stocks (number, location, volume, schedule of renewal), method of distribution, staff involved in distribution, etc.

Step 5

Assess the need for stable iodine prophylaxis outside the PAZ and UPZ. Take appropriate decision or recommendation on the basis of international criteria for stable iodine prophylaxis. See Appendix II for details.

NOTE

If stable iodine prophylaxis is performed, make sure that information about persons who took stable iodine is recorded. Depending on the scale of the emergency and number of people involved, the information could be general (record of dosage taken, age and gender distribution, etc) or more detailed and individualized (name and gender, date of birth, address, daily and total dosage, etc.) However, in both cases, the information on side effects needs to be gathered and documented.

Step 6

Track the situation and assess need to continue administration of stable iodine. Issue order or recommendation accordingly.

NOTE

In case of reactor emergency it could be necessary to continue implementation of the stable iodine prophylaxis for more than one day due to:

- continuation of the release;
- inadvertent ingestion;
- ingrowth of I-132 from decay of Te-132.

Step 7

Terminate stable iodine prophylaxis when it is no longer warranted. Record all actions in logbook.

Purpose

To provide guidance on arrangements for long term medical follow-up after the radiation emergency.

Discussion

The scale of the morbidity and mortality attributable to a particular radiation emergency may be unclear for a prolonged period. Without early capture of key data detailing the hazard and identification of the population that has been placed at risk, proper accounting for the severity of the emergency and possibility of radiation-induced effects will not be possible.

It is necessary to arrange for identification, tracking and long term medical follow-up and treatment of the health effects of people in those groups that are at risk of sustaining a detectable increased incidence of cancer from radiation exposure. The criteria for determining who will receive long term medical follow-up should have the aim of detection of radiation induced cancers at an early stage to allow more effective treatment. These criteria should be based on current knowledge of risk for radiation induced health effects.

Input

- Notification of a radiation emergency with threat to public health;
- Description of emergency, estimation of number of people involved;
- Results of dose assessment, including organ specific doses (ranges of doses received and projected).

Output

- Necessary information (initial register) in place to enable proper epidemiological studies defining the health consequences of the emergency (immediate output);
- Data on need for specialized epidemiological studies (continuing output);
- Data on basic parameters of excess morbidity and mortality in persons recognized as being at significant risk from the emergency (long term output).

Step 1

Determine the need for specialized epidemiological follow-up of affected people based upon criteria set up in advance. For guidance on establishing this criteria see Table F2.

NOTE

The purpose of long term medical follow-up of affected people is to perform regular medical examination, which will enable early diagnosis and effective treatment of radiation-induced health effects. However, it is to be noted that there are statistical and demographical limitations in detectability of radiation-induced excess cancer incidence in the exposed population [45, 46]. In addition to the practical output of the medical follow-up of affected people, there could be scientific justification for a long term follow-up. In this case, the size of population under investigation is defined also by taking into account not only limitations in detectability, but the scientific purposes. In both cases, social and economical factors could influence the size of the cohort.

NOTE

Base inclusion in the registry on objective criteria that indicate a potential for an increase in the incidence of radiation induced cancer or consequences of prenatal exposure (e.g. effective dose of 100 mSv [47] to whole body and radiation weighted dose of 100 mSv to foetus [11].

Step 2

Request from relevant specialists (Incident Commander, Radiation Protection Support Group, etc.) results of dose assessment and other necessary data for establishment of specialized registry.

Step 3

Establish registry of persons to be tracked and receive long term medical follow-up. Minimum initial data set for persons suspected to have been exposed to significant levels of irradiation or contamination should contain:

- basic demographic details (ensure that the correct identity of persons in the registry can be confirmed over time);
- the exact place/location at the moment of the emergency;
- results of survey for contamination (internal and external);
- personal dosimetry results, if available;
- history of any injury – conventional/radiation induced/combined;
- Detail of treatment given.

Step 4

Appoint responsible organization for maintaining register. Establish the places where data will be stored.

Step 5

Ensure that all key national databases are flagged with names of persons in the registry to ensure that key subsequent health events can be linked and examined. The most critical of these databases are: death records; and cancer registries.

Step 6

Ensure that an adequate system of record keeping is in use by all agencies responding to an emergency. In particular, ensure that detailed records are made of:

- inventory of radioactive agents involved;
- identification data for affected population;
- information on dose exposure for affected population;
- log of dose measurements; and
- log of event management.

Step 7

Inform people included in the register of their risk level and of the purpose of the register (using plain language explanation).

NOTE

If no specialized studies are required, national health authorities should, as a minimum, report annual mortality and cancer registry statistics from among the registered population.

WORKSHEETS

Caution: *The worksheets in this section should be adapted to reflect conditions for which they will be applied.*

To be completed by: Medical Response Initiator (Dispatcher)	**WORKSHEET A1** **EMERGENCY REGISTRATION FORM**	*No. _____*

Full Name: _____ Date: _____
(Medical Response Initiator)

Provide copy to: ☐ Emergency Medical Responder Time: _____

☐ Medical Transport Team

☐ Public Health Advisor

Name of caller: _____
(Full name)

Member of: ☐ Public ☐ Facility staff

☐ Emergency Services ☐ Medical Emergency Services

Organization or address of caller: _____

Telephone No of caller: _____ Time of call: _____

Emergency location: _____
(Facility address or site location)

Emergency description: _____

_____

_____

_____

_____

Public involved: ☐ Yes ☐ No

Number of injured victims:_____

Are victims contaminated? ☐ Yes ☐ No ☐ Suspected

What advice was given (by the phone):

_____

_____

_____

Call verified: ☐ Yes ☐ No

Signature_____

To be completed by: Medical Response Initiator (Communication coordinator)	**WORKSHEET A2** **EMERGENCY VICTIM REGISTRATION FORM**	*No. _____*

Full Name: _____ Date: _____
(Medical Response Initiator)

Provide copy to: ☐ Emergency Medical Manager Time: _____

Identification of informant _____
(Full name)

Member of: ☐ Emergency Services ☐ Medical Emergency Services

Call verified: ☐ Yes ☐ No

Emergency location: _____
(Facility address or site location)

Number of emergency victims:_____

Medical status of victims:

A*: ☐ Stable ☐ Unstable B: ☐ Stable ☐ Unstable

C: ☐ Stable ☐ Unstable D: ☐ Stable ☐ Unstable

_____

_____

Radiological status of victims:

Radiological survey performed: ☐ Yes ☐ No

Contamination: ☐ Internal: ☐ Ingestion ☐ Inhalation

☐ External: Radionuclide_____

Activity_____Body area_____

Victims exposed: ☐ Yes (how many:_____) ☐ No (how many_____)

Victims contaminated: ☐ Yes (how many:_____) ☐ No (how many_____)

Contaminated wounds: ☐ Yes ☐ No

Initial decontamination done: ☐ Yes ☐ No

Emergency description: Source_____

Distance from the source for the victim:

A_____,B_____,C_____,D_____

_____

Time of exposure for the victim:

A_____,B_____,C_____,D_____

_____

Estimated dose for the victim:

A_____,B_____,C_____,D_____

_____

Expected time of arrival to the hospital:_____ ***Signature***_____

NOTE: * - A,B,C,D, etc. – letters are used to distinguish different patients at this stage.

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

Surveyed by: _____ Date: _____
(Full name)

Provide to: ☐ Emergency Medical Responder Time: _____

Name of victim: _____ Sex: ☐ M ☐ F

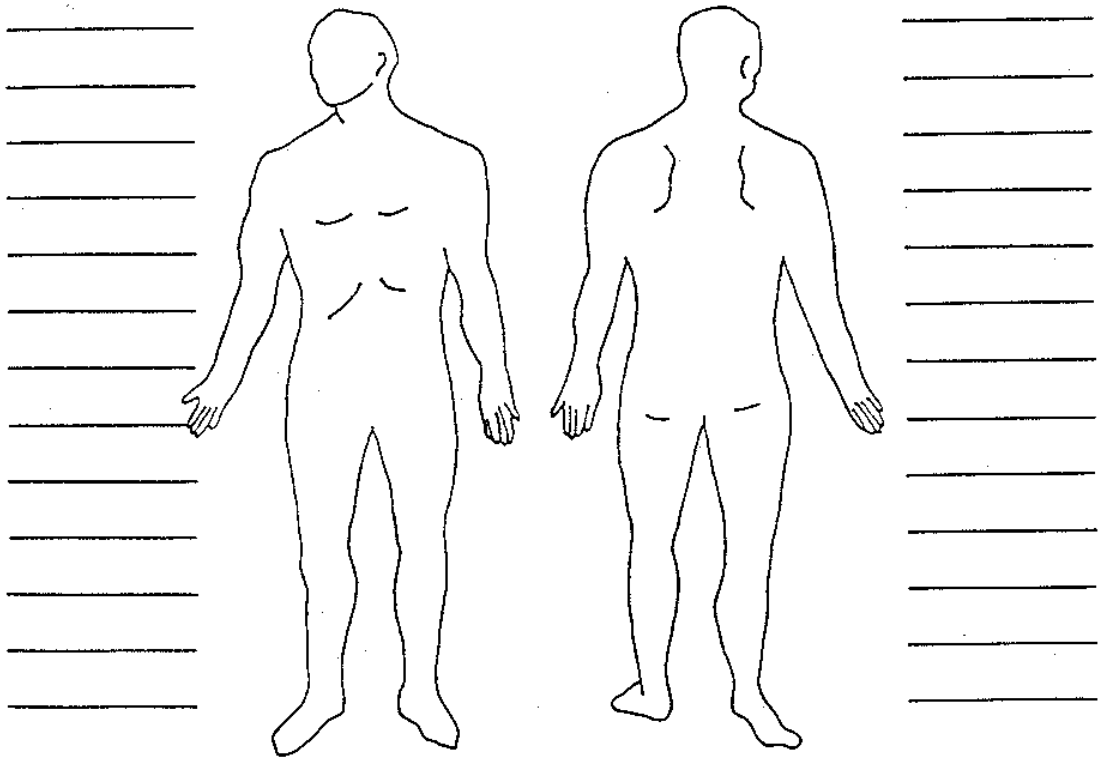
Address: _____

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

Contamination survey

Instrument type: _____ Model: _____

Background reading: _____ Detector active surface: _____ [cm^2]



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

Decontamination procedures performed: ☐ Yes ☐ No

Results of thyroid survey:_____[ ] _____ [ ]
(count rate from neck) [Unit] (count rate from thigh) [Unit]

_____ [ ] _____ [ ]
(background count rate) [Unit] (net count rate) [Unit]

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

Further evaluation at medical facility necessary: ☐ Yes ☐ No

Surveyor signature: _____

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

Full Name: _____ Date: _____
(First Responder)

Provide copy to: ☐ Emergency Medical Responder Time: _____

☐ Public Health Advisor

Information about person involved in the emergency:

Full name:_____

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

ID type and number:_____

Current local full address:_____

Telephone No_____

Current permanent full address:_____

Telephone No_____

Member of: ☐ Public ☐ Facility staff ☐ Emergency Services

Radiological survey done: ☐ Yes ☐ No

If YES, attach Worksheet C1 with results.

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

Distance from the emergency when it happened:_____

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

Duration of exposure:_____ Position of the person:_____

Remarks: _____

_____

_____

Signature:_____

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

Surveyed by: _____ Date: _____
(Full name)

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

Performed in: ☐ Hospital ambulance reception area
☐ Hospital treatment area

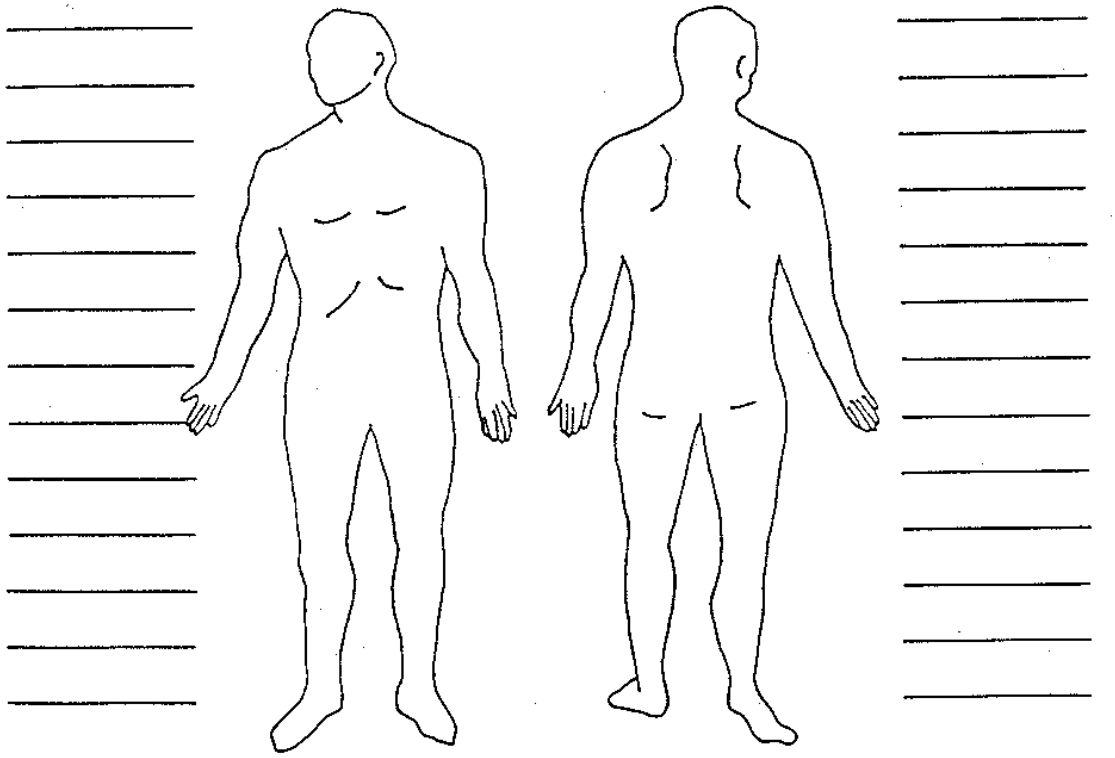
Name of victim: _____ Sex: ☐ M ☐ F

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

Contamination survey

Instrument type: _____ Model: _____

Background reading: _____ Detector active surface: _____ [cm^2]



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

Results of thyroid survey:_____[ ] _____ [ ]
(count rate from neck) [Unit] (count rate from thigh) [Unit]

_____ [ ] _____ [ ]
(background count rate) [Unit] (net count rate) [Unit]

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

Further evaluation at medical facility necessary: ☐ Yes ☐ No

Surveyor signature: _____

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

Full Name: _____ Date: _____
(team member)

Provide copy to: ☐ Emergency Medical Manager Time: _____

☐ Medical Specialist of Appropriate Service (if necessary)

☐ Referral hospital (if necessary)

Identification of the patient:
Full name:_____

Date of birth:_____/_____/_____ Sex: ☐ M ☐ F
Day Month Year
Current local full address:_____
Current permanent full address:_____

Member of: ☐ Public ☐ Personnel ☐ Emergency Workers

Identification of the exposure conditions:
Date of emergency: _____/_____/_____ Presumed time of emergency:_____
Day Month Year

Time of beginning of exposure:_____ Time of end of exposure:_____

Duration of exposure:_____ Position of the patient:_____

Nature of patient's work:_____

The patient had a dosimeter: ☐ Yes ☐ No Dosimeter No:_____
Dosimeter readings:_____ Body location of dosimeter(s):_____

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

Contamination of clothes: ☐ Yes ☐ No ☐ Not checked

Medical findings:
Date of examination: _____/_____/_____

First symptoms:
Clinical state

Nausea: ☐ Yes ☐ No Time of appearance_____Number_____ Duration_____

Vomiting: ☐ Yes ☐ No Time of appearance_____Number_____ Duration_____

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

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

Diarrhoea: ☐ Yes ☐ No Time of appearance_____ Frequency:_____
Temperature:_____ Pulse:_____
Blood pressure:_____
Consciousness:

☐ Normal ☐ Abnormal ☐ Agitation
☐ Delirium ☐ Sleepiness ☐ Coma

Equilibrium disturbance: ☐ Yes ☐ No
Coordination disturbance: ☐ Yes ☐ No
Skin and mucosa: Oedema: ☐ Yes ☐ No
Erythema: ☐ Yes ☐ No
Other:_____
_____

Past history

Any known treatment with X rays or isotopes: ☐ Yes ☐ No
If 'Yes', reasons for treatment:_____
Date of treatment: _____/_____/_____
Place where treatment was given:_____

Treatment and investigations:

Measures taken

Undressing: ☐ Yes ☐ No Decontamination: ☐ Yes ☐ No
Decorporation: ☐ Yes ☐ No. If 'YES', provide details:
Administration pathway: ☐ Aerosol ☐ Bathing ☐ Intravenous
Dose:_____ Results (activity):_____
Stable iodine administration: ☐ Yes ☐ No Time of administration:_____/_____
Date Hour
Dose:_____ Duration:_____

Laboratory tests

Blood samples [Perform a complete and record a complete cell blood count (CBC) with full differential]

First sample
(if possible, before the 3rd hour)

Date:_____/_____/_____
Day Month Year
Time_____

Blood lymphocyte count_____

Cytogenic sample (10 ml) taken: ☐ Yes ☐ No

Second sample
(if possible, 2 hours after the first one)

Date:_____/_____/_____
Day Month Year
Time_____

Blood lymphocyte count _____

HLA typing: ☐ Yes ☐ No

Sample for radioactivity measurement taken:
☐ Yes ☐ No

Third sample
(if possible, 6 hours after second one)

Date:_____/_____/_____
Day Month Year
Time_____

Blood lymphocyte count_____

Fourth sample
(if possible, 6 hours after fourth one)

Date:_____/_____/_____
Day Month Year
Time_____

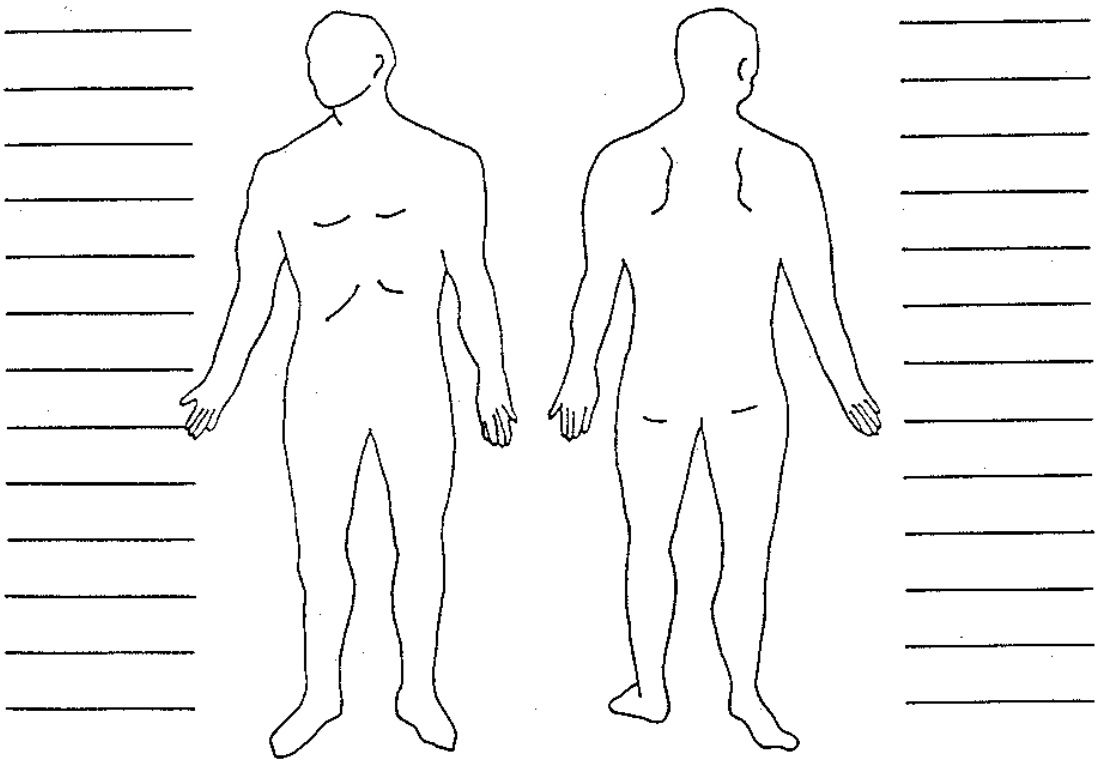
Blood lymphocyte count_____

Urine samples

If applicable, for radioactivity measurement: ☐ Yes ☐ No

It is the first urination after the emergency: ☐ Yes ☐ No

Wound and erythema survey



Remarks: Indicate wound type and erythema in the lines provided in the diagram. Indicate location of the readings by arrows.

Conclusion:

_____
_____
_____
_____
_____
_____

Signature:_____

To be completed by: *Dosimetry Team*	**WORKSHEET D3** **METHODS AND EFFICIENCY OF DECONTAMINATION**	*No.* _____

Decontaminated by: _____ Date: _____
(Full name)

Provide to: ☐ Hospital Emergency Department Response Team

☐ Health/Medical Physicist Time: _____

Performed in: ☐ Hospital ambulance reception area

☐ Hospital treatment area

Name of victim: _____ Sex: ☐ M ☐ F

Contamination survey

Instrument type: _____ Model: _____

Background reading: _____ Detector active surface: _____ [cm^2]

Method:_____
_____
_____

Results of decontamination:

Method used for decontamination	Area decontaminated	Activity before decontamination	Activity after decontamination

Remarks: _____
_____
_____

Signature:_____

To be completed by:	**WORKSHEET D4**	*No.* _____
Bioassay Team	**DATA OF DECORPORATION FOLLOW-UP**	

Full Name: _____ Date: _____
(Responsible Analyst)

Provide copy to: □ Hospital Emergency Department Response Team
□ Health/Medical Physicist (if necessary)

Identification of the patient:

Full name:_____

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

Data of Decorporation Follow-up (through *in-vitro* bioassay):
Radionuclide:_____

Comparison of measured and predicted activities:

Date	Measured Activity [Bq/day]	Predicted Activity [Bq/day]	Ratio*

* *ratio between measured and predicted activity.*

Remarks: _____
_____
_____

Data of Decorporation Follow-up (through *in-vivo* bioassay):
Radionuclide:_____ Counting geometry:_____

Comparison of measured and predicted activities:

Date	Measured Activity [Bq]	Predicted Activity [Bq]	Ratio*

* *ratio between measured and predicted activity*

Remarks: _____
_____
_____

Signature:_____

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

Full Name: _____ Date: _____
(Health/Medical Physicist)

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

Identification of the patient:

Full name:_____
Code: _____ Date of birth:_____/_____/_____

Weight [kg]:_____ Height [cm]: _____

Sex: □ M □ F (Pregnant: □ Yes □ No)

Results of dose estimation:

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

Radiation weighted dose to thyroid: _____, Sv

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

Recommendations: _____
_____
_____

Signature:_____

To be completed by: *Biodosimetry Team*	**WORKSHEET F2** **RESULTS OF CYTOGENETIC DOSIMETRY**	*No.* _____

Full Name: _____ Date: _____
(Responsible Cytogeneticist)

Provide copy to: □ Health/Medical Physicist
□ Hospital Emergency Department Response Team

Identification of the patient:

Full name:_____
Code: _____ Date of birth:_____/_____/_____

Date of blood sampling:_____/_____/_____ Date of analysis:_____/_____/_____

Results of analysis:

2.5.17.3.3 Number of scored cells	
Frequency of dicentrics	
Frequency of centric rings	
Frequency of acentrics	
Estimated absorbed dose [Gy] and 95% CI	

Reference *in-vitro* calibration curve: _____

Radiation type (R): _____ Radiation quality ($\overline{Q}$):_____

Absorbed dose rate: _____ RBE: _____

Calibration curve: _____

Coefficients of calibration curve used for dose assessment: _____

Remarks: _____
_____
_____

Signature:_____

To be completed by: Health/Medical Physicist	**WORKSHEET F3** **INFORMATION FOR NEUTRON DOSE ASSESSMENT FOR CRITICALITY EMERGENCY**	*No. _____*

Full Name: _____ Date: _____
(Health/Medical Physicist)
Provide copy to: □ Hospital Emergency Department Response Team

Identification of the patient:
Full name:_____
Code: _____ Date of birth:_____/_____/_____

Weight [kg]:_____ Height [cm]: _____

Sex: □ M □ F (Pregnant: □ Yes □ No)

Technical Information:

Date and time of exposure:_____

Distance of patient from criticality system: _____m

Position of patient in respect to a criticality system: _____

_____

Type of criticality system:_____

_____

_____

Estimation of neutron spectrum:

□ *Yes* (□ ANISN code □ MCNP code) □ Others (specify):_____

_____

□ No estimation, the reference neutron spectrum to be used from _____

_____

_____

Remarks: _____
_____
_____

Signature:_____

To be completed by: Health/Medical Physicist or Group of specialists	**WORKSHEET F4** **RESULTS OF MEASUREMENT OF ^{24}NA CONCENTRATION IN BLOOD SAMPLE**	*No.* _____

Full Name: _____ Date: _____
(Responsible Analyst)

Provide copy to: □ Hospital Emergency Department Response Team
□ Health/Medical Physicist (if necessary)

Identification of the patient:

Full name:_____

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

Technical Information:

Time of sample collection:_____

Elapsed time between the time of sample collection and the time of exposure:_____

Fraction of ^{24}Na retained in the blood at the time of sample collection:_____

Volume of blood sample: _____cm^3

Counting efficiency:_____

Elapsed time (t_1) between the time of sample collection and the start of counting :_____s

Elapsed time (t_2) between the time of sample collection and the end of counting :_____s

Net counts of ^{24}Na between t_1 and t_2 corrected for background counts: _____cps

Results:

Activity of ^{24}Na at the time of exposure: _____Bq

Concentration of ^{24}Na in the blood sample: _____Bq×cm^{-3}

Remarks: _____

_____

_____

Signature:_____

To be completed by: Health/Medical Physicist or Group of specialists	**WORKSHEET F5** **RESULTS OF NEUTRON DOSE ASSESSMENT**	*No.* _____

Full Name: _____ Date: _____
(Responsible Analyst)

Provide copy to: □ Hospital Emergency Department Response Team
□ Health/Medical Physicist (if necessary)

Identification of the patient:

Full name:_____

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

Technical Information and Results:

Concentration of stable sodium in the blood: _____$g \times cm^3$

Specific activity of ^{24}Na in the blood at the time of exposure: _____ Bq_{Na-24} / g_{Na}

Fluence of the incident neutrons: _____cm^{-2}

RBE-weighted absorbed dose of the neutrons for each organ

Organs	**Absorbed dose [pGy×cm^2] per unit fluence**	**RBE-weighted absorbed dose [pGy-Eq×cm^2] per unit fluence**	**RBE-weighted absorbed dose [Gy-Eq]**
Colon			
Lung			
Red marrow			
Thyroid			

Effective dose of neutron exposure: _____Sv

Results of photon dose assessment _____

_____

_____

Remarks: _____

_____

_____

Signature:_____

To be completed by: Health/Medical Physicist	**WORKSHEET F6** **INFORMATION FOR INTERNAL DOSE ASSESSMENT**	*No. _____*

Full Name: _____ Date: _____
(Health/Medical Physicist)
Provide copy to: □ Hospital Emergency Department Response Team

Identification of patient:
Full name:_____
Code: _____ Date of birth:_____/_____/_____

Weight [kg]:_____ Height [cm]: _____

Sex: □ M □ F (Pregnant: □ Yes □ No)

Technical Information:

Date and time of exposure:_____

Incorporation Pattern: □ Acute intake □ Continuous chronic intake

Intake Pathway: □ Inhalation □ Ingestion □ Skin
□ Wound □ Other

Radionuclides:_____

Chemical and physical forms:_____

Particle size [μm]:_____Bioassay data (attached): ___*in-vivo* ___*in-vitro*

Use of medication or treatment:_____
_____
_____
_____

Results of intake and committed dose assessment
Radionuclide:_____

Date	Type of measurement*	Biokinetic model**	Intake, Bq	Dosimetry model***	Committed effective dose, Sv
Average or most probable			_____		_____

* *indicate if in-vitro (urine or faeces) or in-vivo (whole body, lung, liver, thyroid) was measured*
** *specify the biokinetic model used for intake estimation*
*** *specify the dosimetric model used for dose estimation*

Remarks: _____
_____
_____

Signature:_____

To be completed by: Health/Medical Physicist or Group of specialists	**WORKSHEET F7** **FINAL RESULTS OF INTERNAL DOSE ASSESSMENT**	*No. _____*

Full Name: _____ Date: _____
(Health/Medical Physicist)
Provide copy to: □ Hospital Emergency Department Response Team

Identification of the patient:
Full name:_____
Code: _____ Date of birth:_____/_____/_____

Weight [kg]:_____ Height [cm]: _____

Sex: □ M □ F (Pregnant: □ Yes □ No)

Results of Intake and Committed dose assessment

Date of measurement (dd/mm/yy): _____/_____/_____

Radio-nuclide	Type of measurement*	Biokinetic model**	Intake, [Bq]	Dosimetry model***	Committed effective dose, [Sv]

* *indicate if in-vitro (urine or faeces) or in-vivo (whole body, lung, liver, thyroid) was measured*
** *specify the biokinetic model used for intake estimation*
*** *specify the dosimetric model used for dose estimation*

Radionuclide	Organ or tissue	Time after intake, [d]	Delivered RBE-weighted absorbed dose, [Gy-Eq]

Remarks: _____
_____
_____

Signature:_____

To be completed by: Health/Medical Physicist	**WORKSHEET F8** **INFORMATION FOR *IN-VITRO* BIOASSAY LABORATORY**	*No.* _____

Full Name: _____ Date: _____
(Health/Medical Physicist)

Provide copy to: □ *In-vitro* bioassay laboratory
□ Hospital Emergency Department Response Team

Identification of the patient:

Full name:_____

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

Weight [kg]:_____ Height [cm]: _____

Sex: □ M □ F (Pregnant: □ Yes □ No)

Smoker: □ Yes □ No

Biological sample type:

□ Urine □ Nasal swabs □ Debridement of wound

□ Faeces □ Hair □ Blood

□ Other (specify):_____

Technical information

Purpose of Analysis: □ Screening □ Decontamination follow-up
□ Internal dose assessment □ Decorporation follow-up

Intake Pathway: □ Inhalation □ Ingestion □ Skin □ Wound

Radionuclides:

_____

Chemical and Physical Forms:_____

Use of medication or treatment:_____

_____

_____

_____

Remarks: _____

_____

_____

Signature:_____

To be completed by: Health/Medical Physicist or Group of specialists	**WORKSHEET F9** **RESULTS OF *IN-VITRO* BIOASSAY MEASUREMENTS**	*No.* _____

Full Name: _____ Date: _____
(Responsible Analyst)

Provide copy to: □ Hospital Emergency Department Response Team
□ Health/Medical Physicist (if necessary)

Identification of the patient:

Full name:_____

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

Daily urine and daily faeces measurements:

Radionuclide:_____

Date ___/___/__	**Activity [Bq/day] ± uncertainty [Bq/day]**	
	Urine	**Faeces**

Other biological samples:

Radionuclide:_____

Date ___/___/__	**Concentration [Bq/g or Bq/l] ± uncertainty [Bq/g or Bq/l]**					
	Hair	**Blood**	**Nasal swabs**	**Mouth swabs**	**Excised tissue**	**Other**

Remarks: _____

_____

_____

Signature:_____

To be completed by: Health/Medical Physicist	**WORKSHEET F10** **INFORMATION FOR *IN-VIVO* BIOASSAY LABORATORY**	*No. _____*

Full Name: _____ Date: _____
(Health/Medical Physicist)

Provide copy to: □ *In-vivo* bioassay laboratory
□ Hospital Emergency Department Response Team

Identification of the patient:

Full name:_____

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

Weight [kg]:_____ Height [cm]: _____

Sex: □ M □ F (Pregnant: □ Yes □ No)

Smoker: □ Yes □ No

Technical information

Purpose of Analysis: □ Screening □ Decontamination follow-up
□ Internal dose assessment □ Decorporation follow-up

Intake Pathway: □ Inhalation □ Ingestion □ Skin □ Wound

Radionuclides:

_____

Chemical and physical forms:_____

Use of medication or treatment:_____

_____

_____

_____

Remarks: _____
_____
_____

Signature:_____

To be completed by: Health/Medical Physicist or Group of specialists	**WORKSHEET F11** **RESULTS OF *IN-VIVO* BIOASSAY MEASUREMENTS**	*No.* _____

Full Name: _____ Date: _____
(Responsible Analyst)

Provide copy to: □ Hospital Emergency Department Response Team
□ Health/Medical Physicist (if necessary)

Identification of the patient:

Full name:_____
Code: _____ Date of birth:_____/_____/_____

***In-vivo* measurements:**

Radionuclide:_____

Date	**Activity ± uncertainty [Bq]**			**Other organ or wound**	
___/___/___	**Lung**	**Whole body**	**Thyroid**	**Organ or wound**	**Activity ± uncertainty [Bq]**

Remarks: _____
_____
_____

Signature:_____

APPENDICES

APPENDIX I
HEALTH AUTHORITY RESPONSIBILITIES

Duties of national health authorities include:

1) ensuring that planning for the medical response to a radiation emergencies exists;

2) providing facilities for the management of medical consequences of such emergencies;

3) ensuring that staff trained in the necessary skills are available;

4) exercising their ability to respond to credible emergency scenarios sufficiently frequently to be confident of providing an effective response should an actual emergency arise.

The degree to which resources are devoted to these activities will need to be commensurate with the risks assessed as being present in a particular country. A nation-wide inventory of likely risks is an essential element of undertaking this planning task.

Preparedness stage:

Medical preparedness begins with awareness of where and what type of ionizing radiation and radioactive materials are used in a country. An information database, which needs to be prepared by other involved relevant organizations, and provided for the Ministry of Health, as a background information, should include at least:

- locations where radioactive sources are used;
- types and activities of radioactive sources;
- types of radiation generating devices;
- information regarding the transportation of radioactive materials through any respective area;
- a spectrum of possible emergencies.

On the basis of this background information, the relevant medical organizations need to prepare a list of:

- estimated number of vulnerable population for the potential emergencies;estimated number of casualties (different types) for the potential scenario of malicious use of radioactive materials;
- medical facilities at the local, regional, and national levels;
- specialized medical facilities in other countries;
- medical and support staff, with telephone numbers and addresses, in each respective location;
- specialized national medical centres for treating patients with radiation induced skin lesions or immunosuppression;
- equipment and supplies needed for emergency response, and agreements with ambulance transport services.Data on the number of casualties for the potential scenario of malicious use of radioactive materials are to be used for establishing preparedness to handle mass casualty emergencies. In case of emergency resulting from malicious use of radioactive

materials the probability of mass casualty event is very high. Furthermore, different categories of injuries/involved individuals will seek for medical assistance.

Medical authorities need to be prepared for three waves of people arriving at a hospital from a radiation emergency with mass casualties:

Wave 1: worried-well, who are not injured but worried and get to the hospital on their own and fast. If the staff is not prepared for them, they can clog the hospital and interfere with the treatment of the truly injured that will arrive later;

Wave 2: the injured rescued by the public – bystanders. These arrive next and, while injured, they may not be the most severely injured; and

Wave 3: the injured rescued by emergency response personnel. These will be the last to arrive and will typically be the most severely injured.

Note that Wave 1 and 2 could contain people who have not been monitored or decontaminated.

Therefore, it is crucial to prepare a designated place (not at a hospital or other crucial facility) to assess concerned people (worried-well) for radiation exposure.

All this information needs to be collected at national level and is needed for the development of the medical part of a National Radiation Emergency Plan.

At the local level it is necessary to have a hospital designated to manage radiation victims, if an appropriate hospital exists in the area. However, in the particular situation, depending on the type of the emergency and victims' condition, victims could be admitted to the hospital located closer to the scene of the emergency.Specialized advice may not be routinely available at the scene of the emergency except at medical facilities that use sources such as medical irradiation therapy hospitals, where there are medical professionals who are experienced in dealing with radiation injuries or who have some relevant knowledge.

Response stage:

The duties of a national health authority in the event of an emergency are conducted in co-operation with all appropriate agencies. National health authorities must be able to respond to a radiation emergency in three phases:

Phase 1 – immediate

1) Provide an effective system for the care of those victims affected by an emergency.

2) Provide for public health advice to minimize the risk to the general public (in particular, advise on stable iodine prophylaxis).

3) Re-configure the manner of operation at the time of a major emergency to ensure that a full range of clinical services for the general public not affected by the emergency are maintained.

4) Capture data on population at risk and all information available as to the nature of the emergency to enable effective post-emergency epidemiological surveillance to be performed.

Phase 2 - medium term

1) Reassess and review, with allied departments and agencies, medium to long term protective actions such as food chain restrictions.

2) Provide the population with information as to the likely health effects of the emergency by reference to extant knowledge.

3) Provide for detailed clinical and radiological review of affected persons.

4) Establish a registry of persons to be tracked and to receive long-term medical follow-up. Base inclusion in the registry on objective criteria that indicate potential for an increase in the incidence of radiation induced cancer.

5) Establish and maintain appropriate disease surveillance programme.

6) Begin surveillance of any identified groups at risk, e.g. screening for thyroid disease in children in an area affected by radioactive iodine release.

7) Assist civil authorities in planning a return to normal life for the population affected.

Phase 3 – long term

1) Provide such specialized services as are needed to meet the demand for early recognition and treatment of the stochastic consequences among affected people under a long term medical follow-up programme.

2) Make arrangements to promptly provide the public with the results of medical examinations.

3) Arrange to provide useful, timely truthful, consistent and appropriate information to the public regarding health consequences of the emergency. Use plain language explanation.

4) Maintain appropriate disease surveillance programme.

APPENDIX II
IMMEDIATE PUBLIC HEALTH RESPONSE

Public health response is usually needed in an event resulting in the real or potential involvement of large number of people. Examples of such events could be the following: a reactor emergency, a lost or stolen source, or a malicious act.

Depending on the type of the event, the objective of the public health response will be:

- to protect the public from radiation exposure;
- to decrease the psychological effects.

It should be remembered that medical consequences of radiation emergencies could be attributable not only to radiation exposure itself, but also to the emergency situation in general or following intervention. Examples of the last group of consequences (not attributable to the radiation exposure) are psychological effects, voluntary abortions, demographical changes, consequences of inappropriate medical care, and side effects of iodine prophylaxis.

Actions aimed to decrease psychological effects could be very important in an event resulting in mass casualties (reactor emergencies, malicious events).

In order to protect the public from radiation exposure, the following urgent protective actions are usually undertaken (singly or in combination): sheltering, evacuation, administration of stable iodine (thyroid blocking, or iodine blockade), and restriction of consumption of potentially contaminated food.

Medical response organization is involved to different extents in planning, preparedness, and response implementation of all these protective actions. However, administration of stable iodine is under highest consideration and is the responsibility of the medical response organization.

Stable iodine is only of benefit in protecting the thyroid against radioactive iodine (reactor emergencies resulting in the release of radioactive iodine, laboratory emergencies, malicious events). In the absence of specific evidence of the nature of the releases resulting from a reactor emergency it must be assumed that radioactive iodine is a present hazard.

Basis for thyroid blocking

The mechanism for thyroid protection is based on the physiology of the thyroid gland. The prime function of the thyroid follicular cells are the synthesis, storage, and release of the thyroid hormones thyroxine (T_4) and 3-5-3r triodothyronine (T_3). T_4 and T_3 synthesis occur in three phases: (1). uptake and concentration of inorganic iodide; (2). preceding or concurrent synthesis of thyroglobulin (TG); and (3). iodine organification and iodothyronine formation in the TG molecule.

The iodinated TG is then either hydrolysed to release T_3 and T_4 for secretion or is stored in the thyroid follicular lumina as colloid. So for prevention of radioiodine uptake by the thyroid, it is necessary to satiate it with stable iodine.

Thyroid blocking prevents dose to the gland in case of exposure by inhalation and ingestion of radioiodines. But as there is another measure that prevents radioiodine intake directly

(restriction of potentially contaminated food consumption), thyroid blocking is considered to be primarily used for reduction of doses that result from inhalation.

Time of implementation

To obtain the maximum reduction of the radiation dose to the thyroid, stable iodine should be administered before any intake of radioiodine; otherwise, as soon as practicable thereafter. If stable iodine is administered orally within the six hours preceding the intake of radioactive iodine, the protection provided is almost complete; if stable iodine is administered at the time of radioiodine inhalation, the effectiveness of thyroid blocking is about 90%. The effectiveness of the measure decreases with delay, but the uptake of radioiodine can be reduced to about half if blocking is carried out within a few hours of inhalation.

Main requirements for implementation

The main requirements for implementation of effective thyroid blocking are:

- rapid action for significant effectiveness;
- organization of storage of enough KI tablets to be available during 24 hours a day;
- provision of regular renewal of stock (guaranteed shelf-life is at least 5 years, if stored in dry, dark place);
- consideration of preliminary distribution of tablets among population around NPPs (within precautionary action zone and urgent protective action planning zone);
- existence of clear guidelines for implementation of thyroid blocking, including responsibilities for decision making, criteria, age-dependent dosage;
- preparedness for providing pills of stable KI for more than one day. The reasons for this planning are: continuation of the release for more than one day, inadvertent ingestion, and ingrowth of I-132 from decay of Te-132.

All these questions are to be considered and solved at the stage of preparedness.

The following table provides the generic intervention level for iodine prophylaxis from the international guidance [39, 48].

TABLE II-1. RECOMMENDED GENERIC INTERVENTION LEVEL FOR IODINE PROPHYLAXIS

Protective action	Generic intervention level[a,b]
Iodine prophylaxis	100 mGy[c]

[a] These levels are of avertable dose, i.e. the action should be taken if the dose that can be averted by the action, taking into account the loss of effectiveness due to any delays or for other practical reasons, is greater than the figure given.

[b] The levels in all cases refer to the average over suitably chosen samples of the population, not to the most exposed individuals. However, projected doses to groups of individuals with higher exposures should be kept below the thresholds for deterministic effects.

[c] Avertable committed absorbed dose to the thyroid due to radioiodine. For practical reasons, one intervention level is recommended for all age groups.

A joint IAEA/WHO Technical Committee Meeting to assess and review the international safety standards for intervention in emergency exposure situations involving radioactive iodine, held on 17–19 September 2001 at the IAEA in Vienna advised the IAEA and the WHO Secretariats to consider amendments to the Basic Safety Standards that reflect the following consensus:

— "…The administration of stable iodine to the public is an effective early measure for the protection of the thyroid to prevent deterministic effects and to minimize stochastic effects for persons of any age. However, it is primarily intended for the protection of children and the embryo or foetus.

— The current generic optimized intervention level for iodine prophylaxis of 100 mGy provides an operational basis for prompt decision making and efficient application in the event of a nuclear or radiological emergency. However, as there are strong indications of an age dependence of the risk of induction of thyroid cancer by radioiodine, the administration of stable iodine at significantly lower levels of dose to the thyroid may be recommended in order to take into account the higher sensitivity to radioiodine of children and the embryo or foetus.

— This advice is proffered to serve as a basis for planning, which should be optimized to take into account practical, operational, social and economic considerations; other protective actions to reduce the intake of radioiodine, such as sheltering and control of food supplies, should also be considered.

This advice to the IAEA and WHO Secretariats will only become a requirement if established as such in an IAEA safety standards publication and agreed to by the co-sponsoring organizations of the Basic Safety Standards [39]. Nevertheless, relevant operating and response organizations with responsibilities for the formulation of emergency plans may wish to take it into consideration, particularly the need to give priority to the protection of children, newborn babies and the embryo or foetus …" [1].

Dosage and duration of administration

WHO recommended daily dosage for iodine prophylaxis is shown in Table II-2.

TABLE II-2. RECOMMENDED SINGLE DOSAGE OF STABLE IODINE ACCORDING TO AGE GROUP [49]

Age group	Mass of iodine, mg	Mass of KI, mg	Mass of KIO_3, mg	Fraction of 100 mg tablet
Neonates (birth–1 month)	12,5	16	21	1/8
Infants (1 month–3 years)	25	32	42	1/4
Children (3–12 years)	50	65	85	1/2
Adults and adolescents (over 12 years)	100	130	170	1

Stable iodine should normally be given only once. Evacuation and restriction on foodstuffs should then provide protection from further exposure to radioiodine. If further exposure cannot be prevented by these measures, then repeated daily dosages of iodine could be given for several weeks. The daily dose for repeat prescription is exactly the same as the initial dose given in the table above.

Side effects

From the intake of stable iodine, there is a probability of side effects that differ widely according to the amount of iodine in the diet and the prevalence of thyroid diseases (which is very much higher among elderly people than among infants and young persons). Side effects of stable iodine administration include sialadenitis, gastrointestinal disturbances, allergic reactions and minor rashes, iodine-induced thyrotoxicosis, transient hypothyroidism and goitre.

The probability of adverse effects to the population (hypothyroidism, hyperthyroidism, thyrotoxicosis, goitre) is 10^{-6} to 10^{-7} for a daily therapeutic dose of 300 mg [50]. The risk of death following iodine prophylaxis can be estimated to be of the order of 3×10^{-9}. The risk of side effects will increase with the number of administrations. So it is necessary to discontinue taking stable iodine for population immediately as soon as the uptake of radioiodine falls below the set level.

It is recommended that neonates treated with stable iodine be monitored for the potential effect of transient hypothyroidism by measurement of level for thyroid stimulating hormone (TSH).

Stable iodine should be administered with caution for the following categories, as they have relative contraindication for taking stable iodine:

- thyroid disease, past or present;
- iodine hypersensitivity;
- dermatitis herpetiformis;
- hypocomplementaemic vasculitis.

If the number of doses of stable iodine available is limited, priority for treatment of the public can be targeted. The highest priority groups to receive stable iodine prophylaxis are: newborn babies, lactating mothers, and children.

APPENDIX III
MINISTRY OF HEALTH PLAN FOR MEDICAL RESPONSE TO RADIATION EMERGENCIES (OUTLINE)[25]

TITLE (COVER) PAGE

On the title (cover) page write the title of the plan, approval date, version number and signatures. The title should clearly indicate the organization addressed by the plan (Ministry of health or equivalent). The signatures should include those of the heads of any participating organizations.

CONTENTS

[25] The plan should cover the response arrangements for medical organizations and also for other relevant organizations involved in medical response. Involvement of other organizations should be described to the extent needed for medical organizations in order to be able to fulfil arrangements of general response.

Describe the roles and responsibilities of medical organizations that participate in this plan and of other organizations that have co-operative activities with medical organizations in performing tasks of emergency medical response (e.g. transport service, monitoring service, waste removal). Discuss the responsibility for authorizing/activating the plan and directing the total medical response. Show how responsibilities could differ under different conditions. Describe how responsibilities are delegated or transferred.

2.4 Response organization
Provide a block diagram of general response organization components so that the place of medical organization in the general structure will be clear. Provide a block diagram of the medical response organization components (sections, groups, teams or positions) with a brief description of responsibilities of each 'block' and the emergency facility where these organizational elements will probably perform their responsibilities. A detailed discussion of authorities, responsibilities, and duties of the organizational components should be provided in the implementing procedures for the component.

2.5 Response facilities.
Provide a list and brief description of response facilities.

2.6 Response communications.

2.7 Logistics/resource commitments.

2.8 Concept of operations
Give a brief description of the ideal response of the medical response system in the context of the total response. Provide a separate description of arrangements for a mass casualty event.

3. EMERGENCY RESPONSE PROCESS
Describe the arrangements for the medical response system to perform its functions assigned under the NREP and, where appropriate, to coordinate them under the NREP. Refer to the appropriate implementing procedures that will be used during an emergency to carry out each function.

3.1 Notification, activation and request for assistance.
Describe the tasks and responsibilities for notification, activation, and deployment of the relevant parts for the medical response system. Describe how decisions will be made to activate or deploy the response upon notification of activation under the NREP. Describe the level of activation (normal mode, standby, activated and recovery mode) and criteria for activation levels. Describe how national authorities will be notified of an emergency recognized by physicians (first recognition and triggering the general response). The call lists used for activation and notification should be part of the procedures.

3.2 Emergency management of medical response
Describe the command and control system used to manage the medical response and the relationship to the NREP command and control system.

3.3. Taking urgent protective action
The plan should include the criteria (in an appendix) and organizational components responsible for implementing (or advising on) thyroid blocking, restriction of potentially

contaminated food consumption, evacuation, sheltering, etc. Describe the arrangements for coordinating with other involved organizations.

3.4 Providing information, warnings and instructions to the public
Describe the arrangements for providing the information to the relevant organization to be disseminated to the public.

3.5 Protecting emergency medical personnel
Describe general principles, personal monitoring and control arrangements, dose recording and follow-up.

3.6 Providing medical assistance and mitigating the non-radiological consequences
Describe general principles, provide criteria for triage, screening, long term medical follow-up, monitoring and decontaminating evacuees, etc. Describe the arrangements for long term medical follow-up, and establishment of appropriate registers. Describe the general principles of treatment, transfer of patient to the other national or international medical centres, patient release, and arrangements for psychological support. Describe arrangements for providing medical assistance and mitigating the non-radiological consequences in case of mass casualty event.

3.7 Financial matters

3.8 Maintaining records and management of data

4. EMERGENCY PREPAREDNESS PROCESS
Identify the position responsible and describe the arrangements to perform the functions, listed in the subsections below, that are needed to develop and maintain the capability to respond to an emergency described in the plan.
4.1 Authorities and responsibilities
4.2 Organization
4.3 Coordination
4.4 Plans and procedures
4.5 Logistical support and facilities
4.6 Training
4.7 Exercises
4.8 Quality assurance and programme maintenance

REFERENCES

LIST OF ABBREVIATIONS

DISTRIBUTION LIST
List (and distribute to) all individuals/organizations that are parties to this plan or that will be developing response arrangements that should be consistent with this plan.

APPENDICES
Appendix 1 - Organization authorities, responsibilities and capabilities
Describe the organization authorities, responsibilities, capabilities and resources in emergency situations.

Appendix 2 - Agreements

List (or refer to document listing) and summarize agreements to provide medical assistance (national/international) or memoranda of understanding concerning common response (e.g. with non-medical organizations involved in medical response).

Appendix 3 – Maps and plans related to medical response

Provide (or refer to documents providing) maps showing the locations of threat category I, II and III facilities (including threat category I and II facilities in nearby States), boundaries of the PAZ, UPZ and food restriction radius, other areas of interest or concern, and emergency facilities. Provide the map with pre-established monitoring locations, and emergency facilities.

Appendix 4 - Supporting documentation/plans

List all the supporting documentation/plans relevant for maintenance and implementation of the plan. This should include the plans for various functional areas, such as command and control, logistical and financial support, public affairs and radiological monitoring.

APPENDIX IV
HOSPITAL PLAN FOR MEDICAL RESPONSE TO RADIATION EMERGENCIES (OUTLINE)[25]

TITLE (COVER) PAGE

On the title (cover) page write the title of the plan, approval date, version number and signatures. The title should clearly indicate the organization addressed by the plan (hospital). The signatures should include those of the heads of any participating organizations, such as the local fire brigade.

CONTENTS

Provide a block diagram of the sections, groups, teams or positions within the hospital with a brief description of responsibilities of each 'block' and the emergency facility where these organizational elements will probably perform their responsibilities. A detailed discussion of authorities, responsibilities, and duties of the sections, groups, teams or positions should be provided in the implementing procedures for the component.

2.5 Response facilities.
Provide a list and brief description of hospital facilities which will be used in response.

2.6 Response communications.

2.7 Logistics/resource commitments.

2.8 Concept of operations
Give a brief description of the ideal response of the hospital in the context of the total response. Provide a separate description of arrangements for a mass casualty event.

3. EMERGENCY RESPONSE PROCESS
3.1 Notification, activation and request for assistance.
Describe the level of activation (normal mode, standby, activated and recovery mode) and criteria for activation levels. Describe how national authorities will be notified of an emergency recognized by physicians (first recognition and triggering the general response). The call lists used for activation and notification should be part of the procedures.

3.2 Emergency management of medical response
Describe the command and control system used to manage the medical response in the hospital and the relationship to the national medical command and control system.

3.3. Taking urgent protective action
The plan should include the criteria (in an appendix) and organizational components responsible for implementing (or advising on) thyroid blocking (if applicable). Describe the arrangements for coordinating with other involved organizations.

3.4 Providing information, warnings and instructions to the public
Describe the arrangements for providing the information to the relevant organization to be disseminated to the public.

3.5 Protecting emergency medical personnel
Describe general principles, personal monitoring and control arrangements, dose recording and follow-up.

3.6 Providing medical assistance and mitigating the non-radiological consequences
Describe general principles, provide with the criteria for triage, screening, monitoring and decontaminating evacuees, etc. Describe the general principles of treatment, transfer of patient to the other national or international medical centres, patient release, Emergency area set up, contamination control, personal monitoring, dose assessment, psychological support.

3.7 Financial matters
3.8 Maintaining records and management of data

4. EMERGENCY PREPAREDNESS PROCESS

Identify the position responsible and describe the arrangements to perform the functions, listed in the subsections below, that are needed to develop and maintain the capability to respond to an emergency described in the plan.

4.1 Authorities and responsibilities
4.2 Organization
4.3 Coordination
4.4 Plans and procedures
4.5 Logistical support and facilities
4.6 Training
4.7 Exercises
4.8 Quality assurance and programme maintenance

REFERENCES

LIST OF ABBREVIATIONS

DISTRIBUTION LIST

List (and distribute to) all individuals/organizations that are parties to this plan or that will be developing response arrangements that should be consistent with this plan.

APPENDICES

Appendix 1 - Organization authorities, responsibilities and capabilities

Describe the organization authorities, responsibilities, capabilities and resources in emergency situations.

Appendix 2 - Agreements

List (or refer to document listing) and summarize agreements to provide medical assistance (national/international) or memoranda of understanding concerning common response (e.g. with non-medical organizations involved in medical response).

Appendix 3 – Maps and plans related to medical response

Provide plans of emergency areas (reception, decontamination, treatment, etc. for events with several casualties and mass casualties). Provide the map with pre-established monitoring locations, and emergency facilities.

Appendix 4 - Supporting documentation/plans

List all the supporting documentation/plans relevant for maintenance and implementation of the plan. This should include the plans for various functional areas, such as command and control, logistical and financial support, public affairs and radiological monitoring.

APPENDIX V
MEDICAL RESPONSE STRUCTURE WITHIN EMERGENCY RESPONSE ORGANIZATION [6]

The general response should operate under an integrated incident command system (ICS). In order to be integrated in general response, emergency medical response personnel should understand their roles and functions. The ICS organization is built around five major components: command, planning, operations, logistics and finance/administration. In small-scale incidents/emergencies, one person, the incident commander, may manage or perform all components. Large-scale incidents/emergencies usually require that each component, or *section*, is set up separately. Each of the primary ICS sections may be divided into smaller functions as needed. Typically, the organization is divided into *branches* depending on the nature of the activity having functional or geographic responsibility, *groups* that are responsible for a specified functional assignment, and finally *teams*. The basic structure of ICS is shown in Figure V-1.

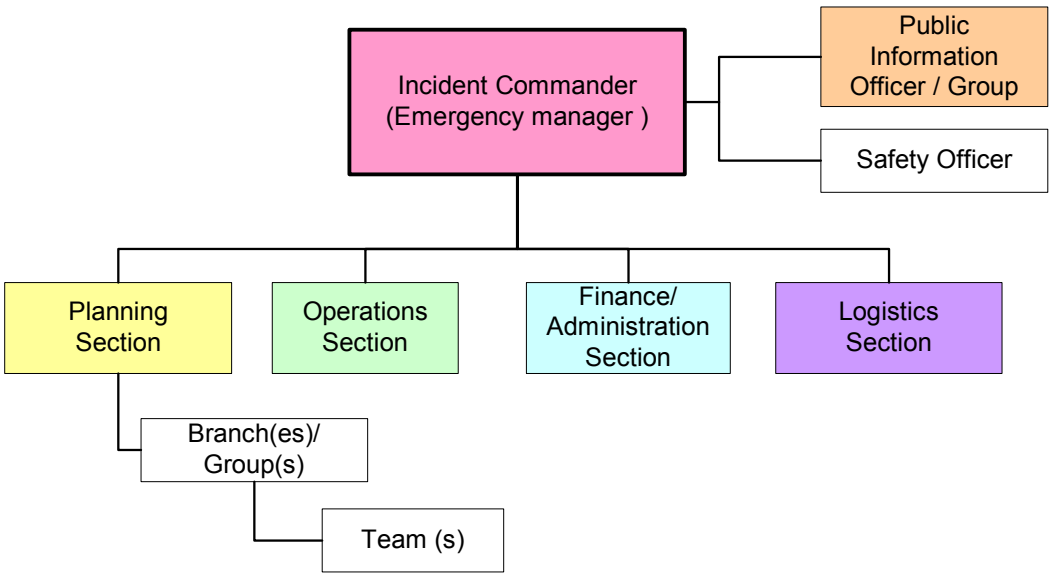


FIG. V-1. Basic structure of ICS organization

In a small scale incident, emergency medical response organization works directly under IC management. If the event becomes more complex, the incident commander adds more staff under the ICS structure. In this case, emergency medical response organization works within the Operations Section, Medical and Radiation Protection Services branch (see Figure V-2).

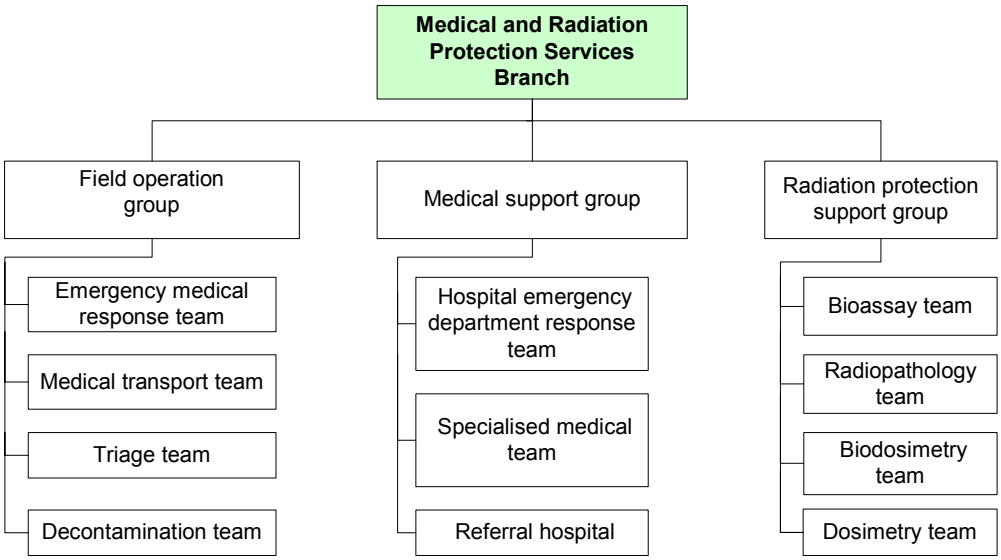


FIG. V-2. Structure of Medical and Radiation Protection Services branch

The medical and radiation protection services branch directs and coordinates the medical assessment and treatment of radiation induced and other injuries. This branch is also responsible for monitoring and controlling the radiation doses received by members of the response organization.

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APPENDIX VI
EQUIPMENT AND SUPPLIES

This appendix presents a list of equipment and supplies recommended for immediate medical response to radiation emergencies to be performed at pre-hospital and hospital levels (depending on national arrangements for distributing or stockpiling some of the mentioned medicine, kits of equipment and supplies could be basic or extended).

Instrumentation

set of standard surgical instruments
equipment for blood transfusion
disposable syringes
blood cell counter
microscope
equipment for preparing blood smears
containers for collecting biological samples
phlebotomy kits
ambubag and mask
defibrillator, batteries and charger
containers for biological sample collection and storage

First aid kit

analgesics
cardiogenic drugs
antihypotensive or antihypertensive drugs
antiemetics
antibiotics
diuretics
topical antibiotic cream
rehydration salts

Radiation survey instruments

multipurpose gamma/beta monitor (2 pcs)
alpha/beta surface contamination monitor
area monitor
check sources
beta/gamma surface contamination monitor (2 pcs)

Personal protection equipment and supplies (per team member)

self-reading dosimeter
permanent dosimeter
protective overalls
overshoes
cotton gloves, vinyl gloves, rubber gloves

General supplies

portable radio with adjustable frequencies
cellular phone
PC (notebook)
spare batteries
critical spare parts
plastic sheets, tapes, bags (different sizes)
surgical clothing
sheets and blankets
portable stretchers
tags and adhesive labels
medical information forms
radiation emergency patient form
drapes
waste bags
administrative supplies
cases for shipment
torch

Decontamination kit

saturated solution of $KMnO_4$
5% $NaHSO_3$
0.2 N H_2SO_4
5% sodium hypochlorite solution
HCl solution 0.1 N
sterile eyewash solution
surgical cotton rolls
cotton applicators for nasal swabs
masking tape
brushes, including nail brushes
paraffin gauze dressings
swabs
nasal catheters
detergents
sterile water for wound and skin
decontamination indelible felt pens for marking contaminated spots

Decorporation kit

required substances (see table below)

Target radionuclides	*Substance*
Caesium	Prussian Blue
Strontium	Alginate, Strontium gluconate or lactate
Radium	Aluminium phosphate
Uranium	Isotonic sodium bicarbonate
Transuranics, lanthanides, manganese, iron, cobalt, zirconium, ruthenium	CaDTPA
Calcium, strontium, barium, radium	Calcium gluconate
Cobalt	Cobalt gluconate
Iodine	Potassium iodine
Strontium, radium	Aluminium phosphate, Barium sulphate, Magnesium sulphate
Mercury, lead, polonium	Dimercaprol
Iron, plutonium	Deferoxamine
Copper, iron, mercury, lead, gold, other heavy metals	Penicillamine
Tritium	Diuretics

Supporting documentation

operational manuals
procedure document
report form for patient transportation
list of WHO/REMPAN collaborating centres
list of phone numbers in the country and procesure for resusting assistance

Laboratory equipment

centrifuge
large refrigerator (for preserving samples)
freezer (for storing samples)
different reagents, depending on the type of samples and radionuclide to be measured

APPENDIX VII
PSYCHOLOGICAL EFFECTS: MANAGEMENT AND PREVENTION CONSIDERATIONS

Recent experience has shown that psychosocial effects of a radiation emergency can far outnumber any direct effects. The widespread public anxiety associated with events such as the Chernobyl and Goiânia emergencies appears to be out of proportion to the radiation induced health effects. Decision makers must take psychological effects into account in emergency management because the reality of public distress has direct relevance for policy makers, public health and medical personnel. Reactions to radiological and nuclear emergencies should be similar in principle, depending on the scope and intensity of the emergency (Table VII-1).

TABLE VII-1. CHARACTERISTICS OF RADIATION EMERGENCIES TO CONSIDER FOR MANAGEMENT OF PSYCHOLOGICAL EFFECTS

Description of the emergency	Emergency	
	Radiological	Nuclear
Scope	Generally confined or limited in scope	Varies from small on-site to large scale severe
Location	Anywhere	In or around a nuclear facility or plant having large amounts of radioactive material
Recognition	Prompt or delayed	Most likely prompt recognition
Occurrence	Unexpected	Emergency considered a possibility

The health consequences of either emergency could be classified as directly related to radiation exposure (deterministic and stochastic effects) and related to emergency situation (health consequences associated with the emergency *per se* or the interventions aimed to reduce/minimize accidental exposure). The paradox is that public health consequences that are directly related to radiation exposure may be limited in number (deterministic effects) or may be relatively numerous but are spread out in time and will possibly never show up as a recognizable increase against the background level of incidence (stochastic effects). Direct effects of exposure are not dependent on awareness or subjective perception of risk. They can be prevented or reduced by rational protective actions to minimize public exposure. On the contrary, health effects related to emergency situation may be widespread both geographically and temporally and may affect a very large number of people, thus far outnumbering any health effects of radiation exposure.Psychological effects in an affected population are one of the most important public health consequences indirectly caused by an emergency or intervention. Protective action aimed to reduce exposure may even be counterproductive with regard to psychological effects. There are following groups of highest risk for development of psychological effects due to radiation emergency: women with young children, pregnant women, those with prior mental disorders, and, sometimes, first responders. From the studies performed after three major radiation emergencies (TMI, Chernobyl and Goiânia), a description of common reactions and psychological consequences can be made. In interviews, individuals relate all their present health problems to radiation, although they either don't know how much exposure they have received (if any) or don't believe the reported doses; they live with fear and worry about developing medical problems and delayed effects of their exposure. Lifestyles have been modified by changes in food consumption, substance abuse, the elimination of some activities and new habits induced. Somatic complaints are reported. Individual coping mechanisms include apathy, avoidance, depression, denial, information seeking, search for the culprit, etc. All these individual reactions were more or less extended and intense, depending on factors connected with the emergency and individual characteristics of the affected people. A psychological impact has many features, generally related to

manifestations of stress. Stress corresponds to a permanent situation of biological, psychic and social maladjustment, which requires alertness, tension and energy on the part of the subject. Prolonged periods of psychological stress can result in physiological changes, psychosomatic and mental health problems and cognitive effects. The physiological changes associated with stress-induced catecholamines can lead to real physical symptoms and illness (such as cardiovascular and gastrointestinal problems, skin rashes, etc.). Psychosomatic problems such as real or imagined symptoms, without evidence of disease or abnormality, and mental health problems such as alcoholism, drug addiction or depression can also be present. In addition, it is clear that continuously living under stress conditions can distract attention and influence thought processes. Stress related psychological effects, including anxiety, will always accompany a radiation emergency whether or not it involves or is expected to involve significant radiation exposure. While the 'stressor' or the causative agent cannot be removed, effort is needed to change the way in which it is perceived. It is recognized that knowledge of radiation and its effects can serve to reduce the fear and anxiety associated with radiation. Frequently, members of the public seek guidance and information about radiological practices or events from physicians and other health care professionals. Unfortunately, medical education does not generally provide physicians with sufficient information to enable them to knowledgeably answer questions about ionizing radiation, health effects of radiation exposure, or protective actions needed in case of radiation emergency. Appropriate medical and emergency information should therefore be made available to them so that they can inform the concerned public before, during and after an emergency. Physicians should also make an effort to learn more about the diagnosis and treatment of radiation injury, even though such injuries are rare.

Public officials, teachers, ministers, psychologists, nurses and others who are in positions of trust and who have the respect of the community should also be offered specific information that would enable them to assist the public during an emergency. This should help to improve public acceptance and compliance should protective actions need to be implemented.

Emergency preparedness near a nuclear plant or facility with the potential for a large emergency should include an ongoing educational programme for the public. It should provide understandable information about radiation, the facility and its safety features, and the protective action that will be advised in the event of an emergency. It must be taken into account that planning and preparation are inconvenient for people because they demand physical and mental effort from an apathetic population (they are usually not aware that it is necessary), and it will not be easy to engage them. At the time of an emergency, clear and simple advice based on internationally endorsed guidance should be given to the public. This will increase public confidence and will help to alleviate stress and anxiety. To minimize the potential for longer term stress in affected population groups, it is essential to resist pressure to introduce protective action within the public domain at levels that are well below those justified on radiological grounds. Social and psychological support programmes should provide help for affected individuals after an emergency. Social assistance is necessary for an affected population, especially for those who have been evacuated or relocated. Grounded and adequate social assistance can prevent the development of additional stress conditions and restore people's self-confidence and confidence in their ability to change their own future. It can also restore confidence in the activities of the authorities.

There are no data about malicious acts involving radioactive material upon which to base the psychological impact. Nevertheless, non-nuclear/radiological terrorism suggests the impact could be very significant.

APPENDIX VIII
PROCEDURE FOR UNDRESSING CONTAMINATED VICTIM [51]

1. Contaminated victim to undress

2. Overalls are rolled up from inside to outside

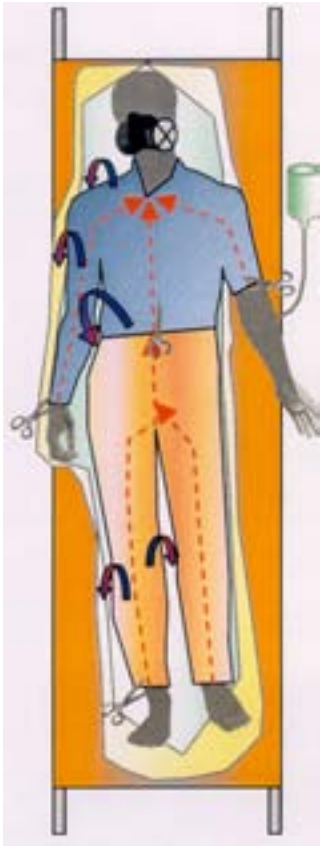
3. Clothes are rolled up from inside to outside

4. Procedure is completed

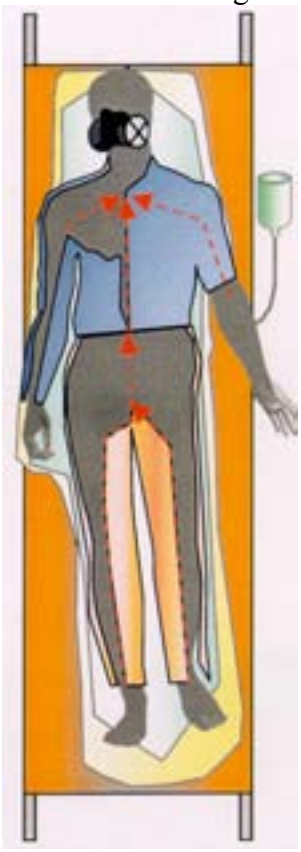
FIG. VIII-1. Undressing standing victim

1. Contaminated victim to undress

2. Cutting clothes after opening of the cover



3. Clothes are fold up from inside to outside along the victim



4. Transfer of undressed victim to uncontaminated bed or stretcher

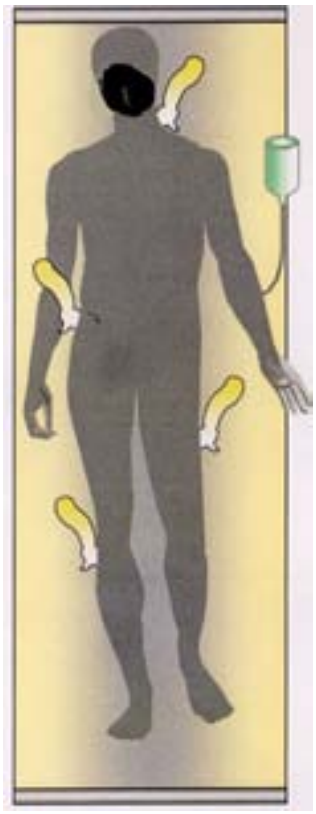


FIG. VIII-2. Undressing lying victim

APPENDIX IX
PLANS OF RECEPTION AREA IN HOSPITAL FOR HANDLING CONTAMINATED CASUALTIES

Each hospital must consider its individual situation and respective facility design. The figures below represent sample set-ups for hospital reception areas for emergencies resulting in several casualties or mass casualties.

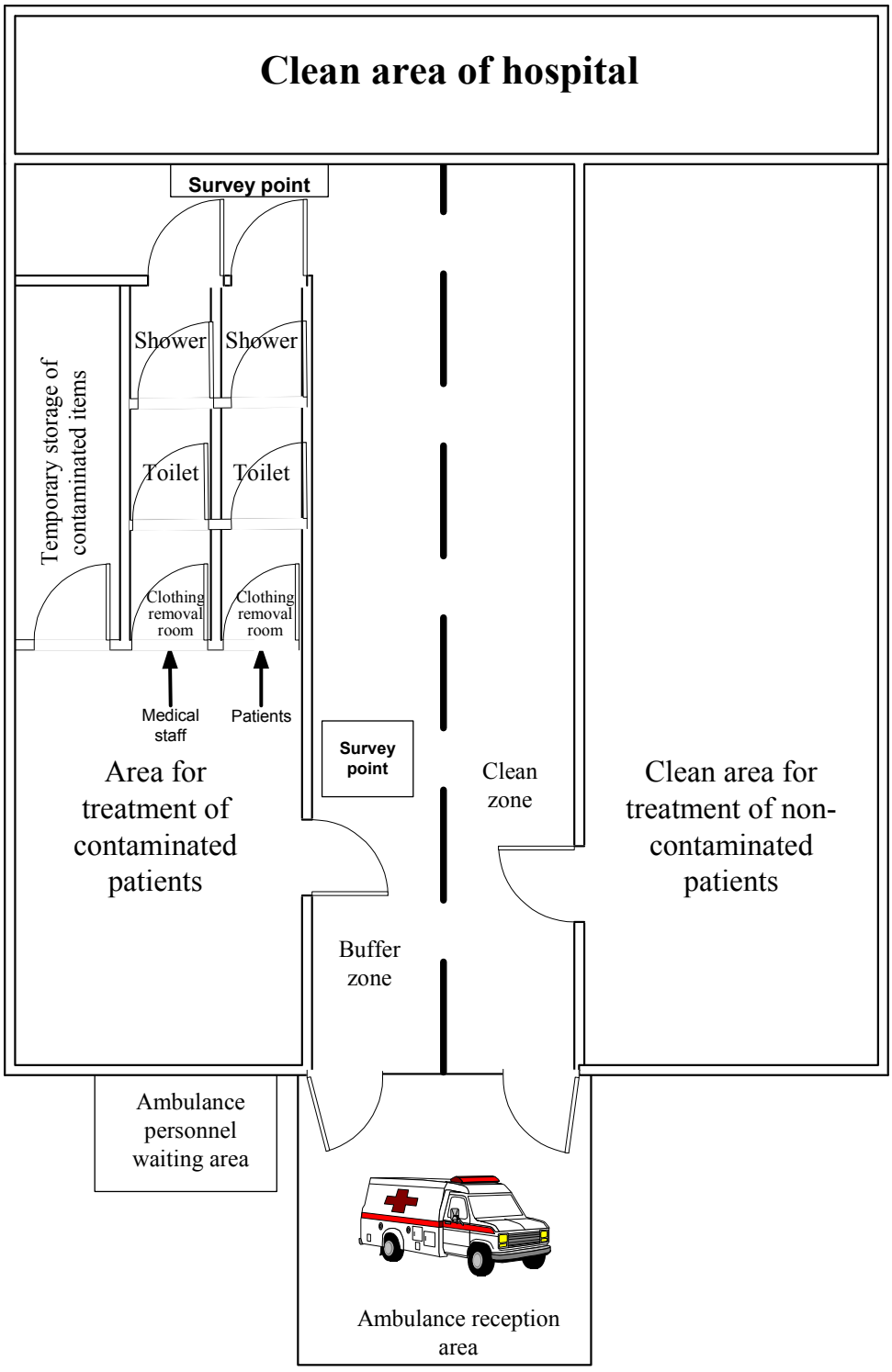


FIG. IX-1. Sample set-up for receiving of one or two patients

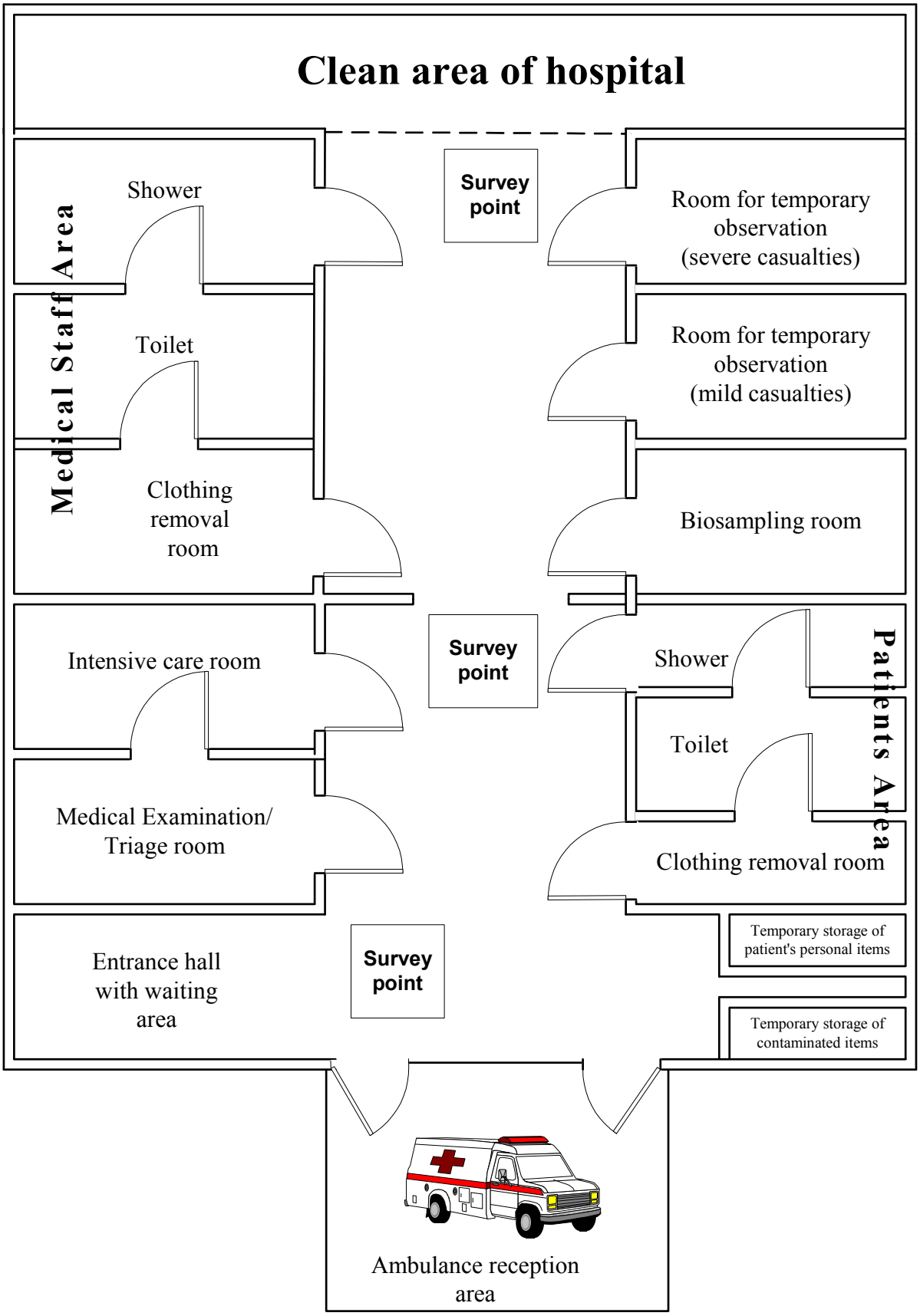


FIG. IX-2. Sample set-up for mass casualties

APPENDIX X
CONSIDERATIONS FOR RESPONSE TO MALICIOUS ACTS INVOLVING RADIOACTIVE MATERIAL

This appendix provides information useful for planning considerations for an emergency resulting from malicious acts involving radioactive material. These terrorist scenarios include the spread of sealed sources, radiological dispersal devices, and the detonation of a crude or sophisticated nuclear weapon [52]. Each scenario may produce multiple casualties although there are distinctions to be made regarding lethal, non-lethal, and psychological consequences (Table X-1).

TABLE X-1. MEDICAL/PUBLIC HEALTH CHARACTERISTICS OF RADIATION EMERGENCIES RESULTING FROM MALICIOUS ACTS INVOLVING RADIOACTIVE MATERIAL

Type of event	Relative casualty-type distribution			
	Lethal		Non-lethal	
	Initial injuries	Delayed injuries	Exposed individuals	Non-exposed and/or psychologically affected individuals
Nuclear weapon	High	High	High	High
Sealed source dispersal	Low	Intermediate	High	High
Radiological dispersal device	Low	Low	Intermediate	High

In general, the generic procedures for medical management of radiation emergencies are the same whether for single or for mass nuclear or radiological casualties. The consequences of malicious acts involving radioactive material, resulting in potentially large numbers of casualties, rapid depletion of medical resources, and limited personnel, dictate a different medical management strategy for emergency response. In the case of such malicious acts, it is important to emphasize those components of accepted general practices that are especially relevant.

Sealed sources spread in the environment do not present a contamination hazard. As long as these sources are intact, contamination is not possible. Sealed sources can result in low level exposures to persons who come near an individual source. However, persons who handle these sources may suffer significant local radiation injury to the skin and underlying tissues. Mass casualties are not expected when sealed sources are considered.

Radiological dispersal devices (RDDs) may be improvized explosive devices, also called ‘dirty bombs’, but can include non-explosive devices that could be used to spread radioactive material as well. RDDs are likely to affect relatively small areas compared to a nuclear detonation. The immediate environment, and persons in the area, will become contaminated as the radioactive material is deposited on surfaces. The most effective protection is to leave the affected area. It is highly unlikely that persons in the contaminated area will have medically significant levels of contamination, either external or internal, but fear and concern regarding personal safety will lead to psychological stress.

A nuclear detonation, with the resultant radiation, blast, and thermal injuries, would be catastrophic in comparison to the malicious acts described above. In addition to numerous prompt fatalities from conventional trauma, the nuclear fallout and associated damage to structures will severely disrupt civil authority and infrastructure, thereby complicating the

delivery of medical care in the affected area. The detonation of a nuclear weapon will result in significant impact on medical response at both pre-hospital and hospital levels. Hundreds to thousands of prompt fatalities are expected in the detonation zone, with an even greater number of persons with blast and burn injuries as one moves away from the detonation zone. The size of the area will be related to the actual yield of the weapon. Triage and initial treatment will affect overall delivery of medical care and stress pre-hospital and hospital resources to their limits. Fallout from these weapon detonations may lead to an even greater number of persons with significant levels of radiation exposure having an even greater impact on the delivery of medical care. Medical resources will be quickly overwhelmed as most survivors will have significant traumatic injuries and thermal burns. The impact of radiation exposure will be secondary to medical management of conventional trauma.

Finally, all malicious acts involving radioactive material must be considered as criminal acts and evidence must be retained for investigation by the proper authorities.

Emergency medical response plans need to be vigilant for potential malicious acts involving radioactive material. Reporting to appropriate authorities of even a single radiation exposure case can contribute to the initial identification of a malicious act involving radioactive material. Such acts can also involve few seriously injured casualties but can evoke public hysteria and panic.

All hazard approach in response to malicious acts involving radioactive material

In the context of the current situation regarding malicious acts with a strategy focused on a massive number of victims, the threat could be focused not only on the radiological risk. In case of a malicious act, it is very difficult to prejudge what type of toxic compounds (nuclear, chemical or biological) or weapons (classical or nuclear) will be used. This new feature leads to the emergence of a new doctrine where any event is to be considered and handled a priori as a nuclear radiological biological chemical (NRBC) event until properly classified. New strategies, including medical ones, are needed to respond to these new risks and a system of all hazards (NRBC) response must be designed for the medical management of radiation emergencies, which will be able to be efficient for any other potential risk, either chemical or biological. The high probability of numerous victims, the potential gravity of the radiation delayed effects and the long, hard and tricky rescue operations require to set up a standardized methodology in order to optimize the efficiency of the resources for the rescue of a maximum number of lives. This methodology allows management of an unclassified event causing mass casualties. Planning medical response in an NRBC event with a large number of casualties requires an optimized national and regional organization of states, special equipment for rescuers and adequate continuous training.

In an NRBC event, besides the classical categories of persons implicated in any nuclear or radiological emergency such as wounded, contaminated and irradiated people, some other categories of persons would be strongly implicated. These other categories are:

- uninjured persons, present on the event site, who feel concerned and worried because they are effectively implicated or they believe to be implicated in the attack;

- rescuers present during a long period on the site of an unclassified event who face contamination, irradiation and even injury in case of a second explosion;

- staff of general hospitals who are not educated and trained as the referral hospital staff and who receive life-threatened victims and face both the contaminated casualties and the problem of radioactive waste and contamination of building and equipment;

- panic-stricken people such as the uncontrollable population on the roads, professionals (rescuers, hospital staff and administrators) if they are not educated, and the media on site and in the hospitals.

Principles of the nuclear and radiological medical responses to NRBC event.

- Medical emergencies have priority over external or internal radiological risk, which is characterized by delayed occurrence of injuries.

- Treatment of internal contamination, enabling decrease in the binding of radionuclides to target organs, is urgent task and must be planned in the logistical support.

- External contamination needs to be handled properly at the earliest stage in order to avoid the secondary dispersion of radionuclides in the environment, the contamination of rescuers and the subsequent contamination of casualties. If there is no time or no equipment for control of external contamination, a systematic undressing and showering of uninjured persons must be planned using any available resources of the rescuers and on-scene responders. All procedures and rescue behaviour must avoid internalizing external contamination at the level of the face.

- Rescuers need to receive training corresponding to each risk of the NRBC event and need to receive adequate equipment to protect themselves before the event is classified (detection of radioactivity, chemical and biological species). In view of the probability of malicious acts resulting in mass casualties, training is to be extended to a large number of rescuers.

- Standard hospital staff needs to receive basic training in order to avoid panic behaviour or refusal to give treatment when receiving casualties of NRBC events.

APPENDIX XI

INTERNATIONAL SYSTEM FOR MEDICAL ASSISTANCE IN RADIATION EMERGENCY

There is a need for international collaboration and for assistance by Member States and international organizations in planning and preparedness for general and medical management of radiation emergencies. The basis for this collaboration is the Convention on Early Notification of a Nuclear Accident (Notification Convention) and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency (Assistance Convention).

Arrangements for response to any nuclear or radiological emergency and the measures for developing, maintaining, exercising and improving these arrangements for all participating international organizations are described in the Joint Radiation Emergency Plan of the International Organizations [53].

The specific roles and functions in medical response to radiation emergencies are entrusted to WHO and the IAEA. Detailed practical arrangements between the WHO and IAEA Secretariats and their Member States and other parties for the notification of a nuclear or radiological emergency and for the exchange of information in support of the Notification Convention and the Assistance Convention and for the provision of assistance under the Assistance Convention are presented in the Concept of Operations for response to a nuclear or radiological emergency, accepted by the WHO and IAEA Secretariats in January 2003.

In accordance with this Concept of Operation, the following system of notification/communication is established between the IAEA and WHO after obtaining the information by the IAEA from the affected State (Fig. XI-1.):

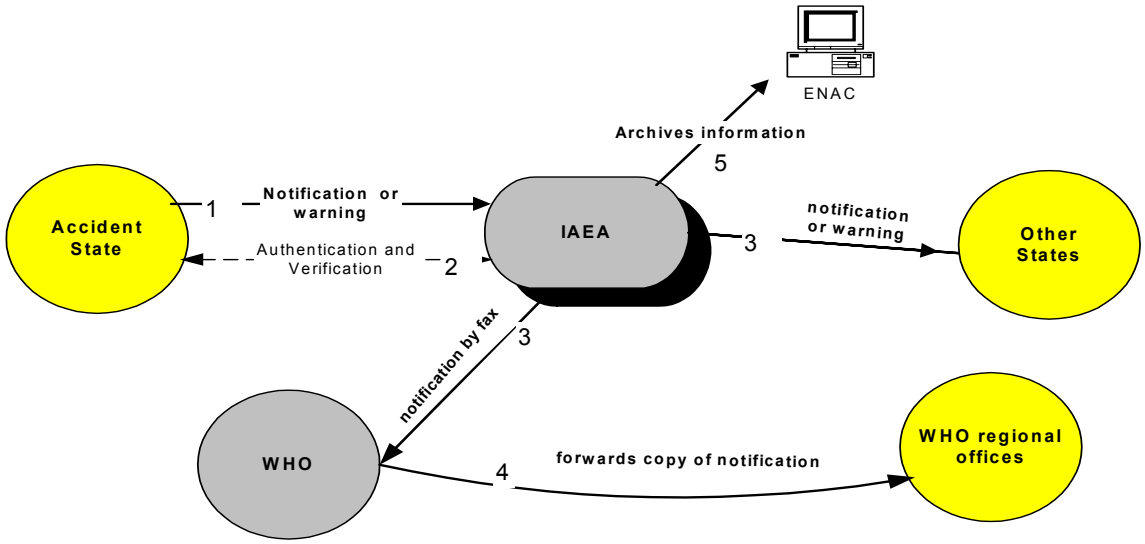


FIG. XI-1. System of notification/communication established between the IAEA and WHO after obtaining information from the affected State

A notifying/reporting State sends a notification or advisory message to the IAEA Emergency Response Centre (ERC), which is a 24-hour contact point for notification and request for assistance.

The ERC authenticates and verifies the information with the national competent authority.

The ERC prepares a cover note and, depending on the emergency class, issues the official notification by fax to all national contact points and WHO HQ.

According to class, the WHO HQ rebroadcasts the notification to the relevant WHO regional centre or to all WHO regional centres.

In case of request for medical assistance under the terms of the Assistance Convention, the ERC will authenticate and verify the request, and will obtain as much information as possible regarding the nature of the emergency, evolution of the medical aspects, and current medical status of those involved.

The ERC rapidly sends an initial field response team to evaluate the situation and to recommend to the IAEA Secretariat the deployment of Emergency Response Network (ERNET) resources [9].

The ERC will inform WHO HQ of the request and the actions taken and will establish continuous liaison.

The initial field response team will assess the situation; suggest a course of treatment taking into account WHO/IAEA guidelines on medical response; and report findings to the competent national authority and to the IAEA Secretariat. The team will otherwise consult and work with the patients' physicians for planning treatment strategies, and will assist if requested.

If continued care of the patients is not feasible in the State, the initial response team will recommend to the IAEA Secretariat and the competent national authority to coordinate their transfer to specialized centres. The requesting State will decide on transferring the patients for treatment to a particular specialized centre. The ERC will arrange for the transport of patients — and if necessary of a local physician accompanying the patient — to the relevant specialized centre(s).

Such centres are usually chosen within the Network of WHO Collaborating Centres on Radiation Emergency Medical Preparedness and Assistance (REMPAN).

APPENDIX XII
DATA FOR INTERNAL DOSE ASSESSMENT IN CASE OF INHALATION AND INGESTION OF RADIONUCLIDES

The dosimetric quantities of effective dose, radiation weighted dose, and RBE-weighted absorbed dose are used in evaluating radiation induced consequences of a nuclear or radiological emergency. They are listed in Table XII-I, illustrated in Figure XII-1 and discussed below.

TABLE XII-1. DOSIMETRY QUANTITIES USED IN A NUCLEAR OR RADIOLOGICAL EMERGENCY ASSESSMENT

Dosimetry quantity	Symbol	Purpose
RBE-weighted absorbed dose	AD_T	For evaluating deterministic health effects induced due to external exposure of an organ or tissue.
Radiation weighted dose	H_T	For evaluating stochastic health effects inducedg due to external exposure of an organ or tissue.
Effective dose	E	For evaluating detriment related to the occurrence of stochastic health effects in an externally exposed population.
Committed RBE-weighted absorbed dose	$AD_T(\Delta)$	For evaluating deterministic health effects induced due to internal exposure of an organ or tissue.
Committed radiation weighted dose	$H_T(\tau)$	For evaluating stochastic health effects induced due to internal exposure of an organ or tissue.
Committed effective dose	$E(\tau)$	For evaluating detriment related to the occurrence of stochastic health effects in an internally exposed population.
Personal dose equivalent	$H_P(d)$	For monitoring external exposure of individual
Ambient dose equivalent	$H^*(d)$	For monitoring radiation field at site of emergency

The RBE-weighted averaged absorbed dose in the organ or tissue (RBE-weighted absorbed dose) (AD_T) is defined as a product of averaged absorbed dose in organ or tissue and the relative biological effectiveness (RBE):

$$AD_T = \sum_R D_{R,T} \times RBE_{R,T}$$

The unit used to express the RBE-weighted absorbed dose in SI is $J \times kg^{-1}$ and is called the *gray-equivalent* (*Gy-Eq*).

The weighted averaged absorbed dose (radiation weighted dose) (H_T) is defined as the product of the averaged absorbed dose in the organ or tissue and the radiation weighting factor w_R:

$$H_T = \sum_R D_{R,T} \times w_R$$

It is expressed in *sieverts* (*Sv*) and it is an organ-specific quantity that may be used for assessment of the risk of any radiation-induced cancer in an organ.

The effective dose (*E)* is widely used for justifying and optimizing protective actions. The effective dose is defined as a product of the radiation weighted dose in an organ or tissue and the tissue weighting factor w_T. Its unit is called the *sievert* (*Sv*). The total effective dose (E_T) includes the dose from external penetrating radiation and intake: $E = \sum_T H_T \times w_T$.

This is the quantity used for the generic reference levels at which certain protective actions are generically justified and optimized for the reference levels for aiding decisions on remediation and for the reference levels at which intervention may not be justified.

The quantities used for radiation monitoring are:

- ambient dose equivalent ($H^*(d)$), i.e. the *dose equivalent* that would be produced by the corresponding aligned and expanded field in the *ICRU sphere* at a depth d on the radius opposing the direction of the aligned field; and
- personal dose equivalent ($H_P(d)$), i.e. the *dose equivalent* in soft tissue below a specified point on the body at an appropriate depth d.

Their units in SI are $J \times kg^{-1}$ and are expressed as *sieverts* (*Sv*).

Ambient dose equivalent and personal dose equivalent are the operational quantities based on the quantity of dose equivalent. The dose equivalent is the product of the *absorbed dose* at a point in the tissue or organ and the appropriate *quality factor* for the type of *radiation* giving rise to the *dose*: $H = \sum_R D_R \times Q_R$.

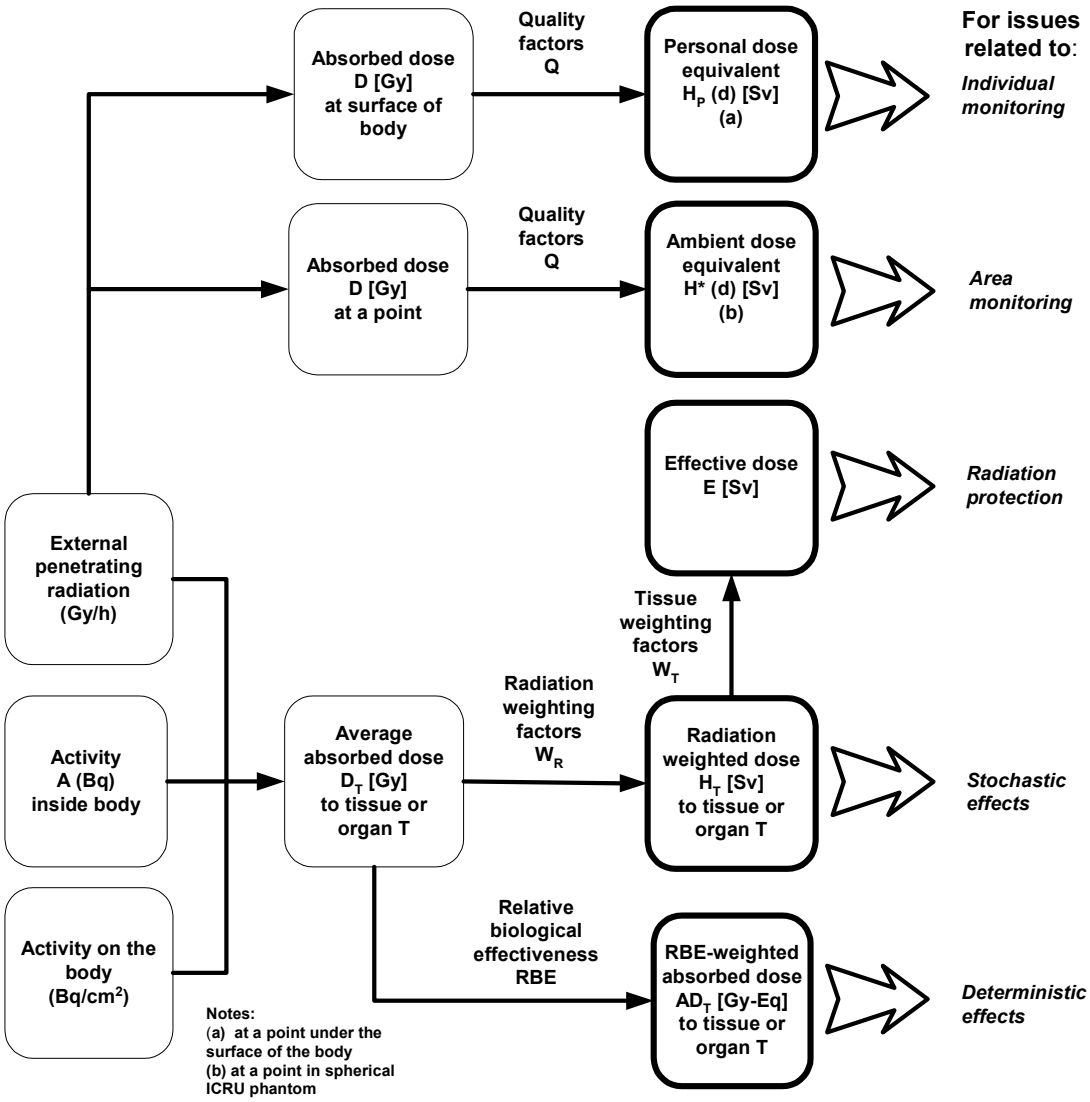


FIG. XII-1. Dosimetric quantities and their application

This appendix presents following data for several elements and their radionuclides:

(1) Data for evaluation of the intake of elements in case of their inhalation and ingestion by workers and members of the public.

(2) Data for evaluation of the doses of internal exposure of radionuclides in case of their inhalation and ingestion intake by workers and members of the public.

The data for the following elements and their radionuclides are included in the appendix:

Element	Radionuclides	Element	Radionuclides
Hydrogen	^{3}H	Thorium	^{228}Th, ^{232}Th
Iron	^{59}Fe	Uranium	^{234}U, ^{235}U, ^{238}U
Cobalt	^{57}Co, ^{58}Co, ^{60}Co	Neptunium	^{237}Np
Strontium	^{85}Sr, ^{89}Sr, ^{90}Sr	Plutonium	^{238}Pu, ^{239}Pu, ^{240}Pu
Ruthenium	^{106}Ru	Americium	^{241}Am
Iodine	^{125}I, ^{131}I, ^{133}I	Curium	^{242}Cm, ^{244}Cm
Caesium	^{134}Cs, ^{137}Cs	Californium	^{252}Cf
Radium	^{226}Ra, ^{228}Ra		

All data are presented for ingestion or inhalation of stable elements. These data may be used for evaluation of the intake of any radioactive isotope of these elements. Data for a particular radionuclide may be derived from the data of the corresponding stable element as follows [54]:

$$f_{T,R}(g,t) = f_{T,[R]}(g,t) \times exp(-\lambda_R \times t)$$

where

$f_{T,R}(g, t)$ – the fraction of the intake of radionuclide R retained in the whole body or in a specific organ T of the person at age g, or having been excreted from the body in 24 hours at time t (in days) after intake (retention or excretion function respectively);

$f_{T,[R]}(g, t)$ - fraction of intake of stable elements *[R]* retained in the whole body or in a specific organ T of the person at age g, or having been excreted from the body in 24 hours at time t (in days) after intake (retention or excretion function respectively);

λ_R - constant of radioactive decay of radionuclide R [55].

t - time after intake, days.

g - age of person under examination.

The data are presented in the following order.

1. In case of public exposure

The data are presented for Reference Man with different ages g:

- adult Reference Man, representing the people more than 17 years of age;
- 0.25 year (3 months) old Reference Man, representing the infants from 0 to 12 months of age;
- 1 years old Reference Man, representing the children more than 1 to 2 years of age;
- 5 years old Reference Man, representing the children more than 2 to 7 years of age;
- 10 years old Reference Man, representing the children more than 7 to 12 years of age;
- 15 years old Reference Man, representing the children more than 12 to 17 years of age.

2. In case of occupational exposure

The data are presented for Reference Worker.

3. In case of intake of radionuclides by inhalation (see Figure AXII.1 for reference).

Part XII-A: For each element:

- intake retention fractions (mass per unit mass intake) for particulate aerosol in respiratory system. These retention functions are universal and may be used for any particulate aerosol with AMAD of 5 μm and σ_g of 2.5 belonged to one of the absorption types (F, M or S) in the case of inhalation;
- compounds and absorption types;
- a table of physical properties of major radionuclides;
- a table of predicted values of retention and excretion functions following single intake by inhalation.

Part XII-B: For each radionuclide:

- committed effective doses per unit intake from inhalation intake of radionuclides by Reference Worker ($e_W^{Inh}(\tau)$) - in Table XII-B1-1;
- committed effective doses per unit intake from inhalation intake of radionuclides by Reference Member of the Public with age g ($e_P^{Inh}(g,\tau)$) - in Table XII-B1-2;
- committed RBE-weighted absorbed doses to the offspring per unit inhalation intake of female Reference Worker ($Ad_{W,offspring}^{Inh}(\Delta)$ for Δ equal to time of *in utero* development)- in Table XII-B2-1;
- committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue T of Reference Worker ($Ad_{W,T}^{Inh}(\Delta)$) for Δ equal to 30 days after acute inhalation intake - in Table XII-B2-2;
- committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue T of Reference Member of the Public with age g ($Ad_{P,T}^{Inh}(g,\Delta)$) for Δ equal to 30 days after acute inhalation intake - in Table XII-B3-1.

Data for exposure of workers presented for single intake by inhalation of gas, vapour and particulate aerosol with AMAD of 5 μm and σ_g of 2.5 belonged to one of the absorption types (F, M or S). Classification of compounds in case of inhalation intake of aerosols presented in Part XII-A.

Data for exposure of members of the public presented for single intake by inhalation of gases, vapours and particulate aerosol with AMAD of 1 μm and σ_g of 2.5 belonged to one of the absorption types (F, M or S). Classification of compounds in case of inhalation intake of aerosols presented in Part XII-A.

4. In case of intake of radionuclides by ingestion.

Part XII-C: For each element:

- compounds and ingestion classes;
- a table of physical properties of major radionuclides;
- a table of predicted values of retention and excretion functions following single intake by ingestion.

Part XII-D: For each radionuclide:

- committed effective doses per unit intake from ingestion intake of radionuclides by Reference Worker ($e_W^{Ing}(\tau)$) - in Table XII-D1-1;
- committed effective doses per unit intake from ingestion intake of radionuclides by Reference Member of the Public with age g ($e_P^{Ing}(g,\tau)$) - in Table XII-D1-2;
- committed RBE-weighted absorbed doses to the offspring per unit ingestion intake of female Reference Worker ($Ad_{W,offspring}^{Ing}(\Delta)$ for Δ equal to time of *in utero* development)- in Table XII-D2-1;
- committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue T of Reference Worker ($Ad_{W,T}^{Ing}(\Delta)$) for Δ equal to 30 days after acute ingestion intake - in Table XII-D2-2;
- committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue of Reference Member of the Public with age g ($Ad_{P,T}^{Ing}(g,\Delta)$) for Δ equal to 30 days after acute ingestion intake of tritium – in Table XII-D3-1;
- committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue T of Reference Member of the Public with age g ($Ad_{P,T}^{Ing}(g,\Delta)$) for Δ equal to 30 days after acute ingestion intake - in Table XII-D3-2;
- committed radiation weighted dose per unit intake $h_{P,T}^{Ing}(g,\tau)$ in thyroid of member of the public after acute ingestion intake of thyroid seeking radionuclides - in Table XII-D3-3.

Data for exposure of workers presented for single intake by ingestion of substances in one of the ingestion classes (A1, A2 or A3). Classification of compounds in case of ingestion intake presented in Part XII-C.

Data for exposure of members of the public presented for single intake by ingestion of radioactive substance with default characteristics.

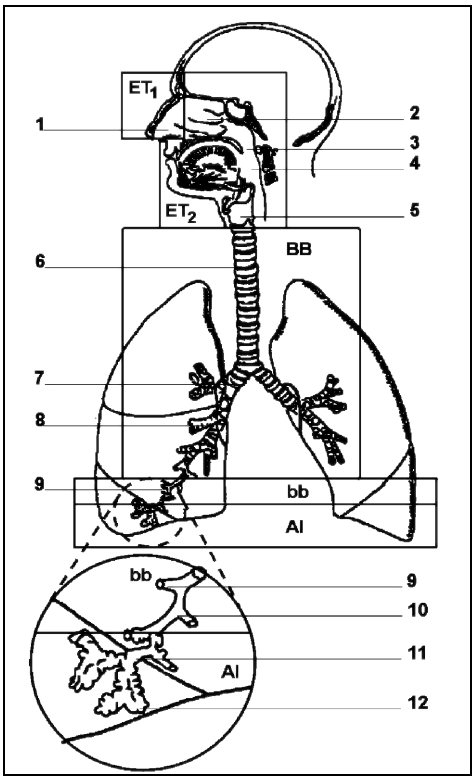


FIG. XII-2. Structure of respiratory system

Extrathoracic airways
ET_1: anterior nasal passage (1);
ET_2: posterior nasal (2) and oral passages (3), the pharynx (4) and larynx (5).
Thoracic regions
bronchial (BB): trachea (6), main bronchi (7) and bronchi (8);
bronchiolar (bb): bronchioles (9) and terminal bronchioles (10);
alveolar-interstitial the gas exchange region (AI): respiratory bronchioles (11) and alveolar duct + alveoli (12)
Lymphatic tissue
associated with the extrathoracic airways (LN_{ET});
associated with the thoracic airways (LN_{TH}).

Basic physical quantities determining a probability of developing severe deterministic effect due to intake of radionuclide are activity and physical and chemical form of radioactive material what was inhaled or ingested. Committed RBE-weighted absorbed dose delivered in organ or tissue play role of representative of these basic quantities in accordance with certain radiobiological model. Till now a limited number of radiobiological models has been developed to predict a probability of developing severe deterministic effects after acute intake of radioactive material. In this Appendix data on committed RBE-weighted absorbed dose in organ or tissue are presented

only for organs in which severe deterministic effects may be developing due to internal exposure; and

only for organs for which risk models of developing severe deterministic effects due to internal exposure are existing.

Values of RBE-weighted absorbed dose were calculated from ICRP Dose coefficients [56, 57] as follows.

1. Irradiation of the offspring

It was assumed for alpha-emitting radionuclides irradiated offspring that committed RBE-weighted absorbed dose (RBE-weighted absorbed dose delivered to offspring during the period of *in utero* development) is a product of committed absorbed dose and RBE, equal to 10 for alpha-particles. For β- and γ-emitting radionuclides was assumed that committed RBE-weighted absorbed dose is equal to committed absorbed dose. The committed absorbed dose was calculated by dividing to w_R the maximal committed effective dose in offspring listed in ICRP Publication 88 [56].

2. Irradiation of the organs for adults and children

It was assumed for alpha-emitting radionuclides that RBE-weighted absorbed dose is a product of absorbed dose and RBE:

RBE = 7 for alpha-particles irradiating AI (Lung),

RBE = 2 for alpha-particles irradiating Red marrow, and

RBE = 0 - for alpha-particles irradiating Colon.

For all β- and γ-emitting radionuclides was assumed that RBE-weighted absorbed dose is equal to absorbed dose.

3. Irradiation of the thyroid

For ^{131}I irradiating thyroid RBE equal to 0.2 was used. It was assumed too that severe deterministic effects in thyroid might be developing only due to internal exposure due to intake of radioiodine. For ^{133}I and ^{125}I was assumed that RBE-weighted absorbed dose in thyroid is equal to absorbed dose.

Part XII-A.
Data for evaluation of the intake of radionuclides in case of inhalation

XII-A1. Intake retention fractions for particulate aerosol in respiratory system

TABLE XII-A1. INHALATION INTAKE RETENTION FRACTIONS (MASS PER UNIT MASS INTAKE) FOR RESPIRATORY SYSTEM (LUNG) [54]*

Time after intake [d]	Type F aerosol		Type M aerosol			Type S aerosol		
	Extra-thoracic airways	Total lung	Thoracic lung	Extra-thoracic airways	Total lung	Thoracic lung	Extra-thoracic airways	Total lung
0.25	2.6E-01	2.6E-01	6.2E-02	2.6E-01	3.3E-01	6.9E-02	2.6E-01	3.3E-01
0.5	2.1E-01	2.1E-01	6.0E-02	2.1E-01	2.7E-01	6.7E-02	2.1E-01	2.7E-01
0.75	1.6E-01	1.6E-01	5.9E-02	1.6E-01	2.2E-01	6.5E-02	1.6E-01	2.3E-01
1	1.3E-01	1.3E-01	5.8E-02	1.2E-01	1.8E-01	6.4E-02	1.2E-01	1.9E-01
1.25	9.7E-02	9.7E-02	5.7E-02	9.7E-02	1.5E-01	6.4E-02	9.7E-02	1.6E-01
1.5	7.6E-02	7.6E-02	5.7E-02	7.5E-02	1.3E-01	6.3E-02	7.6E-02	1.4E-01
1.75	5.9E-02	5.9E-02	5.6E-02	5.9E-02	1.2E-01	6.3E-02	5.9E-02	1.2E-01
2	4.6E-02	4.6E-02	5.6E-02	4.6E-02	1.0E-01	6.3E-02	4.6E-02	1.1E-01
2.25	3.6E-02	3.6E-02	5.6E-02	3.6E-02	9.2E-02	6.3E-02	3.6E-02	9.8E-02
2.5	2.8E-02	2.8E-02	5.5E-02	2.8E-02	8.3E-02	6.2E-02	2.8E-02	9.0E-02
2.75	2.2E-02	2.2E-02	5.5E-02	2.2E-02	7.7E-02	6.2E-02	2.2E-02	8.4E-02
3	1.7E-02	1.7E-02	5.5E-02	1.7E-02	7.2E-02	6.2E-02	1.7E-02	7.9E-02
4	6.2E-03	6.2E-03	5.4E-02	6.4E-03	6.1E-02	6.1E-02	6.4E-03	6.8E-02
5	2.3E-03	2.3E-03	5.3E-02	2.4E-03	5.6E-02	6.1E-02	2.5E-03	6.3E-02
6	8.4E-04	8.4E-04	5.3E-02	1.0E-03	5.4E-02	6.0E-02	1.1E-03	6.1E-02
7	3.1E-04	3.1E-04	5.2E-02	5.0E-04	5.2E-02	6.0E-02	6.0E-04	6.0E-02
8	1.1E-04	1.1E-04	5.1E-02	3.0E-04	5.1E-02	5.9E-02	3.0E-04	5.9E-02
9	0.0E+00	0.0E+00	5.0E-02	2.0E-04	5.1E-02	5.8E-02	3.0E-04	5.9E-02
10	0.0E+00	0.0E+00	5.0E-02	2.0E-04	5.0E-02	5.8E-02	2.0E-04	5.8E-02
20	0.0E+00	0.0E+00	4.3E-02	2.0E-04	4.4E-02	5.3E-02	2.0E-04	5.3E-02
30	0.0E+00	0.0E+00	3.8E-02	2.0E-04	3.9E-02	4.9E-02	2.0E-04	5.0E-02

* For the purposes of radiological protection respiratory system is split into two parts: thoracic lung (shortly named as *lung*) and extrathoracic airways as presented on Fig. XII-2 [58].

XII-A2. Hydrogen

Dosimetric data

TABLE XII-A2-1. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF HYDROGEN [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and its yield
^{3}H (Tritium)	12.35 a	1.90E–3	β^- (0.0057 MeV mean) 100%

Biokinetic data

TABLE XII-A2-2. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR WATER VAPOUR (HTO) OR GAS OF ELEMENTARY HYDROGEN

Time after intake [d]	Workers [54]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.2E-02	2.8E-02	9.4E-02	8.0E-02	5.9E-02	4.8E-02	3.6E-02
2	2.9E-02	2.9E-02	7.7E-02	6.9E-02	5.6E-02	4.7E-02	3.6E-02
3	2.8E-02	2.7E-02	6.1E-02	5.6E-02	4.8E-02	4.2E-02	3.3E-02
4	2.7E-02	2.5E-02	4.9E-02	4.6E-02	4.2E-02	3.7E-02	3.0E-02
5	2.4E-02	2.4E-02	3.9E-02	3.8E-02	3.6E-02	3.3E-02	2.8E-02
6	2.2E-02	2.2E-02	3.1E-02	3.1E-02	3.1E-02	2.9E-02	2.5E-02
7	2.1E-02	2.1E-02	2.5E-02	2.6E-02	2.7E-02	2.6E-02	2.3E-02
8	2.0E-02	1.9E-02	2.0E-02	2.1E-02	2.3E-02	2.3E-02	2.1E-02
9	1.8E-02	1.8E-02	1.6E-02	1.8E-02	2.0E-02	2.0E-02	2.0E-02
10	1.7E-02	1.7E-02	1.3E-02	1.5E-02	1.7E-02	1.8E-02	1.8E-02

TABLE XII-A2-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR VAPOUR OF ORGANICALLY BOUND HYDROGEN (OBT)

Time after intake [d]	Workers [54]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.3E-02	1.4E-02	5.8E-02	4.2E-02	3.0E-02	2.4E-02	1.8E-02
2	2.3E-02	2.3E-02	7.9E-02	5.8E-02	4.6E-02	3.7E-02	2.8E-02
3	2.2E-02	2.2E-02	7.0E-02	5.1E-02	4.3E-02	3.5E-02	2.7E-02
4	2.1E-02	2.1E-02	6.0E-02	4.5E-02	3.9E-02	3.2E-02	2.6E-02
5	2.0E-02	2.0E-02	5.1E-02	4.0E-02	3.5E-02	2.9E-02	2.4E-02
6	1.9E-02	1.9E-02	4.4E-02	3.5E-02	3.2E-02	2.7E-02	2.3E-02
7	1.8E-02	1.8E-02	3.9E-02	3.1E-02	2.9E-02	2.5E-02	2.2E-02
8	1.7E-02	1.8E-02	3.4E-02	2.8E-02	2.6E-02	2.3E-02	2.0E-02
9	1.7E-02	1.7E-02	3.0E-02	2.5E-02	2.4E-02	2.1E-02	1.9E-02
10	1.6E-02	1.6E-02	2.6E-02	2.3E-02	2.2E-02	2.0E-02	1.8E-02

XII-A3. Iron

Dosimetric data

TABLE XII-A3-1. IRON COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Iron	Oxides, hydroxides and halides	M (Default for public)
	All unspecified compounds	F

TABLE XII-A3-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF IRON [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Fe-59	44.5 d	1.56E–2	γ (1.1 MeV) 56%, γ (1.29 MeV) 44%

TABLE XII-A3-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR IRON OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.5E-01	3.7E-01	4.4E-01	4.4E-01	3.8E-01	3.9E-01	3.5E-01
2	4.0E-01	3.0E-01	3.7E-01	3.5E-01	3.1E-01	3.1E-01	2.9E-01
3	3.4E-01	2.7E-01	3.5E-01	3.1E-01	2.8E-01	2.8E-01	2.7E-01
4	3.2E-01	2.6E-01	3.4E-01	2.9E-01	2.7E-01	2.7E-01	2.6E-01
5	3.1E-01	2.5E-01	3.3E-01	2.9E-01	2.6E-01	2.6E-01	2.5E-01
6	3.0E-01	2.5E-01	3.3E-01	2.9E-01	2.6E-01	2.6E-01	2.5E-01
7	3.0E-01	2.5E-01	3.3E-01	2.8E-01	2.6E-01	2.6E-01	2.5E-01
8	3.0E-01	2.5E-01	3.3E-01	2.8E-01	2.6E-01	2.6E-01	2.5E-01
9	3.0E-01	2.5E-01	3.3E-01	2.8E-01	2.6E-01	2.6E-01	2.5E-01
10	3.0E-01	2.5E-01	3.3E-01	2.8E-01	2.6E-01	2.6E-01	2.5E-01
20	3.0E-01	2.5E-01	3.3E-01	2.8E-01	2.6E-01	2.6E-01	2.5E-01
30	3.0E-01	2.5E-01	3.2E-01	2.8E-01	2.6E-01	2.6E-01	2.5E-01

TABLE XII-A3-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR IRON OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	6.1E-04	5.1E-04	2.2E-03	1.2E-03	4.9E-04	5.8E-04	4.2E-04
2	5.2E-05	4.5E-05	2.9E-04	1.0E-04	7.2E-05	6.5E-05	3.6E-05
3	3.4E-05	2.9E-05	1.2E-04	4.7E-05	4.2E-05	4.0E-05	2.2E-05
4	2.4E-05	2.0E-05	6.6E-05	2.8E-05	2.5E-05	2.6E-05	1.5E-05
5	1.7E-05	1.5E-05	4.6E-05	2.0E-05	1.6E-05	1.8E-05	1.1E-05
6	1.4E-05	1.2E-05	3.8E-05	1.7E-05	1.1E-05	1.3E-05	8.4E-06
7	1.1E-05	9.3E-06	3.4E-05	1.6E-05	8.1E-06	9.8E-06	6.8E-06
8	9.3E-06	7.9E-06	3.1E-05	1.5E-05	6.5E-06	8.0E-06	5.8E-06
9	8.2E-06	6.9E-06	3.0E-05	1.4E-05	5.7E-06	7.0E-06	5.1E-06
10	7.3E-06	6.1E-06	2.9E-05	1.3E-05	5.2E-06	6.3E-06	4.7E-06
20	5.3E-06	4.4E-06	2.8E-05	1.2E-05	4.6E-06	5.3E-06	3.7E-06
30	5.2E-06	4.3E-06	2.7E-05	1.2E-05	4.5E-06	5.2E-06	3.6E-06

TABLE XII-A3-5. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR IRON OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.0E-01	3.4E-01	4.0E-01	4.0E-01	3.6E-01	3.6E-01	3.3E-01
2	2.9E-01	2.4E-01	2.7E-01	2.6E-01	2.4E-01	2.4E-01	2.3E-01
3	1.9E-01	1.9E-01	2.1E-01	1.9E-01	1.8E-01	1.8E-01	1.8E-01
4	1.5E-01	1.7E-01	1.8E-01	1.7E-01	1.6E-01	1.6E-01	1.6E-01
5	1.3E-01	1.6E-01	1.7E-01	1.6E-01	1.5E-01	1.5E-01	1.6E-01
6	1.3E-01	1.6E-01	1.7E-01	1.5E-01	1.5E-01	1.4E-01	1.5E-01
7	1.2E-01	1.6E-01	1.7E-01	1.5E-01	1.5E-01	1.4E-01	1.5E-01
8	1.2E-01	1.6E-01	1.7E-01	1.5E-01	1.4E-01	1.4E-01	1.5E-01
9	1.2E-01	1.5E-01	1.6E-01	1.5E-01	1.4E-01	1.4E-01	1.5E-01
10	1.2E-01	1.5E-01	1.6E-01	1.5E-01	1.4E-01	1.4E-01	1.5E-01
20	1.2E-01	1.5E-01	1.6E-01	1.4E-01	1.4E-01	1.3E-01	1.4E-01
30	1.1E-01	1.4E-01	1.5E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01

TABLE XII-A3-6. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR IRON OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.4E-04	8.7E-05	5.1E-04	2.2E-04	8.5E-05	1.0E-04	7.0E-05
2	1.4E-05	1.0E-05	8.6E-05	2.5E-05	1.5E-05	1.4E-05	8.0E-06
3	8.7E-06	6.8E-06	3.7E-05	1.2E-05	9.1E-06	9.0E-06	5.2E-06
4	6.3E-06	5.2E-06	2.2E-05	8.0E-06	6.1E-06	6.3E-06	3.9E-06
5	4.8E-06	4.2E-06	1.6E-05	6.6E-06	4.4E-06	4.8E-06	3.1E-06
6	3.9E-06	3.6E-06	1.4E-05	5.9E-06	3.4E-06	3.9E-06	2.7E-06
7	3.3E-06	3.3E-06	1.3E-05	5.6E-06	2.9E-06	3.3E-06	2.4E-06
8	2.9E-06	3.0E-06	1.2E-05	5.4E-06	2.6E-06	3.0E-06	2.2E-06
9	2.7E-06	2.8E-06	1.2E-05	5.2E-06	2.4E-06	2.8E-06	2.1E-06
10	2.5E-06	2.7E-06	1.2E-05	5.1E-06	2.3E-06	2.7E-06	2.0E-06
20	1.9E-06	2.3E-06	1.1E-05	4.8E-06	2.1E-06	2.3E-06	1.8E-06
30	1.9E-06	2.2E-06	1.1E-05	4.7E-06	2.0E-06	2.3E-06	1.7E-06

XII-A4. Cobalt

Dosimetric data

TABLE XII-A4-1. COBALT COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Cobalt	Oxides, hydroxides, halides and nitrates	S
	All unspecified compounds	M (Default for public)

TABLE XII-A4-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF COBALT [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and its yield
Co-57	271 d	2.56E-3	γ (0.122 MeV) 85.6%, γ (0.137 MeV) 10.6%
Co-58	70.8 d	9.79E–3	γ (0.511 MeV) 30%, γ (0.811 MeV) 99.4%
Co-60	5.27 a	3.60E–4	γ (1.17 MeV) 99.9%, γ (1.33 MeV) 100%

Biokinetic data

TABLE XII-A4-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR COBALT OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.8E-01	3.3E-01	3.8E-01	3.9E-01	3.4E-01	3.5E-01	3.2E-01
2	2.6E-01	2.2E-01	2.3E-01	2.4E-01	2.2E-01	2.2E-01	2.1E-01
3	1.5E-01	1.7E-01	1.7E-01	1.7E-01	1.6E-01	1.6E-01	1.6E-01
4	1.1E-01	1.4E-01	1.4E-01	1.4E-01	1.3E-01	1.3E-01	1.4E-01
5	9.1E-02	1.3E-01	1.2E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
6	8.3E-02	1.3E-01	1.2E-01	1.2E-01	1.2E-01	1.1E-01	1.2E-01
7	7.9E-02	1.3E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
8	7.6E-02	1.2E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
9	7.4E-02	1.2E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
10	7.2E-02	1.2E-01	1.1E-01	1.1E-01	1.1E-01	1.0E-01	1.1E-01
20	6.1E-02	1.0E-01	9.0E-02	9.1E-02	9.2E-02	8.9E-02	9.9E-02
30	5.3E-02	9.3E-02	7.9E-02	8.1E-02	8.2E-02	8.0E-02	8.8E-02

TABLE XII-A4-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR COBALT OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.1E-02	1.3E-02	2.3E-02	1.6E-02	1.4E-02	1.4E-02	1.3E-02
2	8.4E-03	5.9E-03	1.0E-02	6.8E-03	6.2E-03	6.4E-03	5.7E-03
3	3.5E-03	2.6E-03	4.3E-03	2.9E-03	2.7E-03	2.7E-03	2.5E-03
4	2.1E-03	1.6E-03	2.6E-03	1.8E-03	1.7E-03	1.7E-03	1.6E-03
5	1.7E-03	1.3E-03	2.1E-03	1.5E-03	1.3E-03	1.3E-03	1.3E-03
6	1.5E-03	1.2E-03	1.8E-03	1.3E-03	1.2E-03	1.2E-03	1.1E-03
7	1.3E-03	1.1E-03	1.7E-03	1.2E-03	1.1E-03	1.1E-03	1.1E-03
8	1.2E-03	1.0E-03	1.5E-03	1.1E-03	1.0E-03	1.0E-03	9.8E-04
9	1.1E-03	9.5E-04	1.4E-03	1.0E-03	9.3E-04	9.4E-04	9.2E-04
10	9.9E-04	8.9E-04	1.3E-03	9.5E-04	8.7E-04	8.8E-04	8.6E-04
20	4.7E-04	5.5E-04	6.7E-04	5.4E-04	5.2E-04	5.1E-04	5.3E-04
30	2.9E-04	4.2E-04	4.4E-04	3.8E-04	3.8E-04	3.7E-04	4.0E-04

TABLE XII-A4-5. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR COBALT OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.02E-1	4.9E-02	6.2E-02	6.8E-02	5.6E-02	5.8E-02	4.7E-02
2	1.41E-1	7.0E-02	8.6E-02	9.5E-02	7.9E-02	8.2E-02	6.7E-02
3	7.14E-2	3.7E-02	4.5E-02	5.0E-02	4.1E-02	4.3E-02	3.6E-02
4	3.00E-2	1.6E-02	1.9E-02	2.1E-02	1.8E-02	1.9E-02	1.6E-02
5	1.21E-2	7.0E-03	8.2E-03	9.0E-03	7.7E-03	7.9E-03	6.8E-03
6	5.01E-3	3.3E-03	3.7E-03	4.0E-03	3.5E-03	3.6E-03	3.3E-03
7	2.30E-3	1.9E-03	2.0E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.27E-3	1.3E-03	1.3E-03	1.3E-03	1.3E-03	1.3E-03	1.3E-03
9	8.69E-4	1.1E-03	1.0E-03	1.1E-03	1.0E-03	1.0E-03	1.1E-03
10	7.02E-4	1.0E-03	8.9E-04	9.2E-04	9.2E-04	9.0E-04	1.0E-03
20	4.14E-4	7.0E-04	5.7E-04	6.2E-04	6.3E-04	6.2E-04	7.0E-04
30	3.00E-4	5.4E-04	4.2E-04	4.6E-04	4.8E-04	4.7E-04	5.3E-04

TABLE XII-A4-6. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR COBALT OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.9E-01	3.4E-01	3.9E-01	3.9E-01	3.5E-01	3.5E-01	3.2E-01
2	2.5E-01	2.2E-01	2.3E-01	2.4E-01	2.2E-01	2.2E-01	2.1E-01
3	1.4E-01	1.7E-01	1.5E-01	1.6E-01	1.5E-01	1.5E-01	1.6E-01
4	9.8E-02	1.4E-01	1.2E-01	1.3E-01	1.3E-01	1.3E-01	1.4E-01
5	8.0E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.1E-01	1.3E-01
6	7.3E-02	1.3E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
7	7.0E-02	1.3E-01	9.9E-02	1.1E-01	1.1E-01	1.1E-01	1.2E-01
8	6.8E-02	1.2E-01	9.7E-02	1.1E-01	1.1E-01	1.1E-01	1.2E-01
9	6.7E-02	1.2E-01	9.6E-02	1.0E-01	1.1E-01	1.0E-01	1.2E-01
10	6.6E-02	1.2E-01	9.5E-02	1.0E-01	1.1E-01	1.0E-01	1.2E-01
20	5.9E-02	1.1E-01	8.7E-02	9.5E-02	9.7E-02	9.4E-02	1.1E-01
30	5.4E-02	1.0E-01	8.0E-02	8.8E-02	9.0E-02	8.7E-02	9.9E-02

TABLE XII-A4-7. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR COBALT OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	6.1E-03	6.2E-04	1.7E-03	8.7E-04	6.9E-04	7.2E-04	5.9E-04
2	2.9E-03	3.5E-04	8.4E-04	4.4E-04	3.9E-04	4.0E-04	3.4E-04
3	1.1E-03	1.4E-04	3.4E-04	1.8E-04	1.6E-04	1.6E-04	1.4E-04
4	6.5E-04	8.4E-05	2.0E-04	1.0E-04	9.1E-05	9.4E-05	8.1E-05
5	4.9E-04	6.5E-05	1.5E-04	8.1E-05	7.0E-05	7.2E-05	6.3E-05
6	4.2E-04	5.7E-05	1.3E-04	7.0E-05	6.1E-05	6.2E-05	5.5E-05
7	3.8E-04	5.2E-05	1.2E-04	6.3E-05	5.5E-05	5.6E-05	5.0E-05
8	3.4E-04	4.8E-05	1.1E-04	5.8E-05	5.1E-05	5.2E-05	4.6E-05
9	3.0E-04	4.4E-05	9.6E-05	5.3E-05	4.7E-05	4.8E-05	4.3E-05
10	2.8E-04	4.1E-05	8.8E-05	4.9E-05	4.3E-05	4.4E-05	4.0E-05
20	1.5E-02	2.3E-05	4.1E-05	2.5E-05	2.3E-05	2.3E-05	2.3E-05
30	1.5E-02	1.7E-05	2.5E-05	1.6E-05	1.6E-05	1.6E-05	1.6E-05

TABLE XII-A4-8. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR COBALT OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.12E-01	5.5E-02	7.6E-02	7.7E-02	6.3E-02	6.6E-02	5.3E-02
2	1.56E-01	8.0E-02	1.1E-01	1.1E-01	9.1E-02	9.5E-02	7.7E-02
3	7.90E-02	4.2E-02	5.7E-02	5.7E-02	4.8E-02	5.0E-02	4.1E-02
4	3.30E-02	1.9E-02	2.4E-02	2.5E-02	2.1E-02	2.1E-02	1.8E-02
5	1.31E-02	7.9E-03	1.0E-02	1.0E-02	8.6E-03	8.9E-03	7.7E-03
6	5.34E-03	3.7E-03	4.4E-03	4.4E-03	3.9E-03	4.0E-03	3.6E-03
7	2.37E-03	2.0E-03	2.2E-03	2.2E-03	2.0E-03	2.1E-03	2.0E-03
8	1.26E-03	1.4E-03	1.4E-03	1.4E-03	1.3E-03	1.3E-03	1.4E-03
9	8.35E-04	1.2E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.2E-03
10	6.67E-04	1.1E-03	9.2E-04	9.4E-04	9.6E-04	9.4E-04	1.1E-03
20	4.38E-04	8.1E-04	6.7E-04	7.0E-04	7.2E-04	7.0E-04	8.1E-04
30	3.43E-04	6.5E-04	5.3E-04	5.6E-04	5.8E-04	5.6E-04	6.5E-04

XII-A5. Strontium

Dosimetric data

TABLE XII-A5-1. STRONTIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Strontium	Strontium titanate ($SrTiO_3$)	S
	All unspecified compounds	F (Default for public)

TABLE XII-A5-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF STRONTIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Sr-85	64.8 d	1.07E–2	γ (0.51 MeV) 98%
Sr-89	50.5 d	1.37E–2	β^- (0.58 MeV mean) 100%
Sr-90	29.1 a	6.53E–5	β^- (0.20 MeV mean) 100%, β^- of ^{90}Y (0.99 MeV mean) 100%

TABLE XII-A5-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR STRONTIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.9E-01	3.1E-01	4.3E-01	4.0E-01	3.5E-01	3.7E-01	3.4E-01
2	3.2E-01	2.3E-01	3.5E-01	3.0E-01	2.6E-01	2.9E-01	2.8E-01
3	2.4E-01	1.8E-01	3.1E-01	2.5E-01	2.2E-01	2.5E-01	2.5E-01
4	2.1E-01	1.6E-01	3.0E-01	2.3E-01	1.9E-01	2.2E-01	2.4E-01
5	1.8E-01	1.4E-01	2.9E-01	2.1E-01	1.8E-01	2.1E-01	2.3E-01
6	1.7E-01	1.3E-01	2.8E-01	2.0E-01	1.7E-01	2.0E-01	2.2E-01
7	1.6E-01	1.3E-01	2.7E-01	1.9E-01	1.6E-01	1.9E-01	2.2E-01
8	1.5E-01	1.2E-01	2.7E-01	1.8E-01	1.5E-01	1.9E-01	2.2E-01
9	1.5E-01	1.2E-01	2.6E-01	1.7E-01	1.5E-01	1.8E-01	2.1E-01
10	1.4E-01	1.1E-01	2.6E-01	1.7E-01	1.4E-01	1.8E-01	2.1E-01
20	1.0E-01	8.3E-02	2.4E-01	1.4E-01	1.1E-01	1.5E-01	1.9E-01
30	8.7E-02	6.9E-02	2.3E-01	1.2E-01	9.7E-02	1.4E-01	1.8E-01

TABLE XII-A5-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR STRONTIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.1E-02	5.4E-02	1.8E-02	4.3E-02	4.2E-02	2.9E-02	1.5E-02
2	2.2E-02	1.8E-02	6.2E-03	1.5E-02	1.5E-02	1.0E-02	5.3E-03
3	1.5E-02	1.2E-02	5.5E-03	1.2E-02	1.1E-02	8.6E-03	4.7E-03
4	1.1E-02	9.2E-03	5.0E-03	9.5E-03	9.1E-03	7.3E-03	4.2E-03
5	9.1E-03	7.3E-03	4.4E-03	8.0E-03	7.6E-03	6.3E-03	3.8E-03
6	7.4E-03	5.9E-03	4.0E-03	6. 6E-03	6.4E-03	5.5E-03	3.4E-03
7	6.2E-03	5.0E-03	3.6E-03	5.9E-03	5.5E-03	4.8E-03	3.0E-03
8	5.3E-03	4.3E-03	3.3E-03	5.1E-03	4.8E-03	4.2E-03	2.7E-03
9	4.7E-03	3.7E-03	2.9E-03	4.5E-03	4.2E-03	3.8E-03	2.5E-03
10	4.1E-03	3.3E-03	2.7E-03	4.0E-03	3.7E-03	3.4E-03	2.3E-03
20	1.8E-03	1.4E-03	1.2E-03	1.6E-03	1.5E-03	1.4E-03	9.7E-04
30	9.5E-04	7.5E-04	6.3E-04	8.7E-04	8.0E-04	7.2E-04	5.1E-04

TABLE XII-A5-5. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR STRONTIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.9E-01	3.4E-01	3.9E-01	4.0E-01	3.5E-01	3.5E-01	3.2E-01
2	2.5E-01	2.2E-01	2.3E-01	2.4E-01	2.2E-01	2.2E-01	2.1E-01
3	1.4E-01	1.7E-01	1.5E-01	1.6E-01	1.5E-01	1.5E-01	1.6E-01
4	9.2E-02	1.4E-01	1.2E-01	1.3E-01	1.3E-01	1.3E-01	1.4E-01
5	7.4E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
6	6.7E-02	1.3E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
7	6.4E-02	1.3E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
8	6.3E-02	1.2E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
9	6.2E-02	1.2E-01	9.9E-02	1.1E-01	1.1E-01	1.1E-01	1.2E-01
10	6.1E-02	1.2E-01	9.8E-02	1.1E-01	1.1E-01	1.0E-01	1.2E-01
20	5.6E-02	1.1E-01	9.0E-02	9.6E-02	9.8E-02	9.6E-02	1.1E-01
30	5.1E-02	1.1E-01	8.4E-02	9.0E-02	9.2E-02	8.9E-02	1.0E-01

TABLE XII-A5-6. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR STRONTIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	8.5E-04	4.2E-04	3.0E-04	3.8E-04	3.5E-04	2.5E-04	1.2E-04
2	3.3E-04	1.8E-04	1.2E-04	1.6E-04	1.5E-04	1.1E-04	4.8E-05
3	2.2E-04	1.2E-04	1.0E-04	1.2E-04	1.1E-04	8.7E-05	4.2E-05
4	1.6E-04	9.1E-05	9.4E-05	1.0E-04	9.2E-05	7.4E-05	3.8E-05
5	1.3E-04	7.4E-05	8.5E-05	8.7E-05	7.8E-05	6.5E-05	3.4E-05
6	1.1E-04	6.2E-05	7.7E-05	7.6E-05	6.7E-05	5.7E-05	3.1E-05
7	8.9E-05	5.4E-05	7.0E-05	6.6E-05	5.9E-05	5.1E-05	2.9E-05
8	7.7E-05	4.7E-05	6.3E-05	5.8E-05	5.2E-05	4.6E-05	2.7E-05
9	6.7E-05	4.3E-05	5.8E-05	5.2E-05	4.6E-05	4.2E-05	2.4E-05
10	6.0E-05	3.9E-05	5.4E-05	4.7E-05	4.2E-05	3.8E-05	2.3E-05
20	2.9E-05	2.3E-05	2.7E-05	2.4E-05	2.2E-05	1.9E-05	1.3E-05
30	1.8E-05	1.7E-05	1.7E-05	1.6E-05	1.6E-05	1.3E-05	8.8E-06

XII-A6. Ruthenium

Dosimetric data

TABLE XII-A6-1. RUTHENIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Ruthenium	Halides	M (Default for public)
	Oxides and hydroxides	S
	All unspecified compounds	F

TABLE XII-A6-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF RUTHENIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Ru-106	1.01 a	1.88E–3	γ (0.51 MeV) 21%, γ of ^{106}Rh (0.62 MeV) 10%, γ (1.1 MeV) 1%, β^- (1.51 MeV mean) 78.8%

Biokinetic data

TABLE XII-A6-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR RUTHENIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.1E-01	3.3E-01	3.9E-01	4.0E-01	3.5E-01	3.6E-01	3.2E-01
2	3.5E-01	2.5E-01	2.8E-01	2.9E-01	2.6E-01	2.6E-01	2.4E-01
3	2.7E-01	2.1E-01	2.3E-01	2.3E-01	2.1E-01	2.1E-01	2.0E-01
4	2.3E-01	1.9E-01	2.1E-01	2.1E-01	1.9E-01	1.9E-01	1.8E-01
5	2.2E-01	1.8E-01	1.9E-01	1.9E-01	1.8E-01	1.8E-01	1.7E-01
6	2.0E-01	1.7E-01	1.8E-01	1.8E-01	1.7E-01	1.7E-01	1.6E-01
7	2.0E-01	1.6E-01	1.8E-01	1.8E-01	1.6E-01	1.6E-01	1.6E-01
8	1.9E-01	1.6E-01	1.7E-01	1.7E-01	1.6E-01	1.6E-01	1.5E-01
9	1.8E-01	1.5E-01	1.6E-01	1.6E-01	1.5E-01	1.5E-01	1.5E-01
10	1.8E-01	1.5E-01	1.6E-01	1.6E-01	1.5E-01	1.5E-01	1.4E-01
20	1.4E-01	1.1E-01	1.2E-01	1.2E-01	1.1E-01	1.1E-01	1.1E-01
30	1.2E-01	9.6E-02	1.0E-01	1.0E-01	9.5E-02	9.6E-02	9.3E-02

TABLE XII-A6-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR RUTHENIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.6E-02	2.9E-02	3.3E-02	3.3E-02	2.9E-02	2.9E-02	2.8E-02
2	1.1E-02	9.6E-03	1.0E-02	1.0E-02	9.5E-03	9.6E-03	9.3E-03
3	7.6E-03	6.4E-03	6.9E-03	6.9E-03	6.4E-03	6.4E-03	6.2E-03
4	6.8E-03	5.7E-03	6.2E-03	6.2E-03	5.7E-03	5.7E-03	5.5E-03
5	6.3E-03	5.3E-03	5.7E-03	5.8E-03	5.2E-03	5.3E-03	5.1E-03
6	5.9E-03	4.9E-03	5.3E-03	5.3E-03	4.9E-03	4.9E-03	4.8E-03
7	5.4E-03	4.6E-03	4.9E-03	5.0E-03	4.5E-03	4.5E-03	4.4E-03
8	5.1E-03	4.2E-03	4.6E-03	4.6E-03	4.2E-03	4.2E-03	4.1E-03
9	4.7E-03	4.0E-03	4.3E-03	4.3E-03	3.9E-03	3.9E-03	3.8E-03
10	4.4E-03	3.7E-03	4.0E-03	4.0E-03	3.6E-03	3.7E-03	3.6E-03
20	2.3E-03	1.9E-03	2.1E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
30	1.5E-03	1.2E-03	1.3E-03	1.3E-03	1.2E-03	1.2E-03	1.2E-03

TABLE XII-A6-5. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR RUTHENIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.9E-01	3.4E-01	3.9E-01	4.0E-01	3.5E-01	3.5E-01	3.2E-01
2	2.7E-01	2.3E-01	2.4E-01	2.5E-01	2.2E-01	2.3E-01	2.2E-01
3	1.6E-01	1.7E-01	1.7E-01	1.7E-01	1.7E-01	1.6E-01	1.7E-01
4	1.2E-01	1.5E-01	1.4E-01	1.4E-01	1.4E-01	1.4E-01	1.5E-01
5	1.0E-01	1.4E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.4E-01
6	9.2E-02	1.4E-01	1.2E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
7	8.8E-02	1.3E-01	1.2E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
8	8.5E-02	1.3E-01	1.2E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
9	8.4E-02	1.3E-01	1.2E-01	1.2E-01	1.2E-01	1.1E-01	1.2E-01
10	8.2E-02	1.3E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
20	7.0E-02	1.1E-01	9.7E-02	9.8E-02	9.8E-02	9.6E-02	1.1E-01
30	6.6E-02	1.0E-01	9.0E-02	9.2E-02	9.2E-02	8.9E-02	9.8E-02

TABLE XII-A6-6. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR RUTHENIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.7E-03	3.9E-03	6.1E-03	4.7E-03	4.0E-03	4.1E-03	3.8E-03
2	2.0E-03	1.5E-03	2.3E-03	1.7E-03	1.6E-03	1.6E-03	1.5E-03
3	1.3E-03	1.0E-03	1.5E-03	1.1E-03	1.0E-03	1.0E-03	9.8E-04
4	1.2E-03	9.2E-04	1.3E-03	1.0E-03	9.2E-04	9.4E-04	8.8E-04
5	1.1E-03	8.7E-04	1.3E-03	9.6E-04	8.7E-04	8.8E-04	8.4E-04
6	1.0E-03	8.2E-04	1.2E-03	9.1E-04	8.3E-04	8.3E-04	8.0E-04
7	9.8E-04	7.9E-04	1.1E-03	8.7E-04	7.8E-04	7.9E-04	7.6E-04
8	9.2E-04	7.5E-04	1.1E-03	8.3E-04	7.5E-04	7.5E-04	7.2E-04
9	8.7E-04	7.2E-04	9.9E-04	7.9E-04	7.1E-04	7.2E-04	6.9E-04
10	8.2E-04	6.9E-04	9.4E-04	7.6E-04	6.8E-04	6.8E-04	6.6E-04
20	5.0E-04	4.8E-04	5.9E-04	4.9E-04	4.6E-04	4.6E-04	4.6E-04
30	3.6E-04	3.9E-04	4.4E-04	3.8E-04	3.7E-04	3.7E-04	3.8E-04

TABLE XII-A6-7. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR RUTHENIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.9E-01	3.4E-01	3.9E-01	3.9E-01	3.5E-01	3.5E-01	3.2E-01
2	2.6E-01	2.2E-01	2.3E-01	2.4E-01	2.2E-01	2.2E-01	2.1E-01
3	1.5E-01	1.7E-01	1.5E-01	1.6E-01	1.5E-01	1.5E-01	1.6E-01
4	1.1E-01	1.4E-01	1.2E-01	1.3E-01	1.3E-01	1.3E-01	1.4E-01
5	8.7E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.1E-01	1.3E-01
6	8.0E-02	1.3E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
7	7.7E-02	1.3E-01	9.8E-02	1.1E-01	1.1E-01	1.1E-01	1.2E-01
8	7.5E-02	1.2E-01	9.6E-02	1.1E-01	1.1E-01	1.0E-01	1.2E-01
9	7.3E-02	1.2E-01	9.5E-02	1.0E-01	1.1E-01	1.0E-01	1.2E-01
10	7.2E-02	1.2E-01	9.4E-02	1.0E-01	1.1E-01	1.0E-01	1.2E-01
20	6.4E-02	1.1E-01	8.4E-02	9.3E-02	9.5E-02	9.2E-02	1.0E-01
30	6.3E-02	1.1E-01	8.1E-02	9.0E-02	9.2E-02	8.9E-02	1.0E-01

TABLE XII-A6-8. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR RUTHENIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μ [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.3E-03	2.4E-04	3.4E-04	3.4E-04	2.7E-04	2.8E-04	2.3E-04
2	9.5E-04	1.2E-04	1.5E-04	1.5E-04	1.3E-04	1.3E-04	1.1E-04
3	5.8E-04	6.8E-05	8.9E-05	8.9E-05	7.5E-05	7.8E-05	6.6E-05
4	5.1E-04	6.0E-05	7.8E-05	7.8E-05	6.6E-05	6.8E-05	5.8E-05
5	4.7E-04	5.6E-05	7.2E-05	7.2E-05	6.1E-05	6.3E-05	5.4E-05
6	4.4E-04	5.2E-05	6.8E-05	6.8E-05	5.7E-05	5.9E-05	5.1E-05
7	4.1E-04	4.9E-05	6.4E-05	6.4E-05	5.4E-05	5.6E-05	4.8E-05
8	3.8E-04	4.7E-05	6.0E-05	6.0E-05	5.1E-05	5.2E-05	4.5E-05
9	3.6E-04	4.4E-05	5.7E-05	5.7E-05	4.8E-05	4.9E-05	4.3E-05
10	3.4E-04	4.2E-05	5.3E-05	5.4E-05	4.5E-05	4.7E-05	4.1E-05
20	1.8E-04	2.7E-05	3.1E-05	3.2E-05	2.8E-05	2.8E-05	2.6E-05
30	1.2E-04	2.0E-05	2.2E-05	2.2E-05	2.0E-05	2.1E-05	1.9E-05

XII-A7. Iodine

Dosimetric data

TABLE XII-A7-1. IODINE COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Iodine	All compounds	F

TABLE XII-A7-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF IODINE [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
I-125	60.1 d	1.15E–2	X (0.027-0.032 MeV) 140%, γ (0.035 MeV) 6.7%
I-131	8.04 d	8.62E–2	β^- (0.19 MeV mean) 89%, γ (0.36 MeV) 81%
I-133	20.8 h	0.80	β^- (0.41 MeV mean) 97%, γ (0.53 MeV) 86%

Biokinetic data

TABLE XII-A7-3. INHALATION INTAKE RETENTION IN THYROID (MASS PER UNIT MASS INTAKE) FOR IODINE OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.3E-01	9.3E-02	1.0E-01	1.1E-01	9.5E-02	9.8E-02	9.0E-02
2	1.4E-01	9.9E-02	1.1E-01	1.1E-01	9.9E-02	1.0E-01	9.5E-02
3	1.4E-01	9.8E-02	1.0E-01	1.1E-01	9.7E-02	1.0E-01	9.4E-02
4	1.4E-01	9.8E-02	9.5E-02	1.0E-01	9.4E-02	1.0E-01	9.3E-02
5	1.4E-01	9.7E-02	9.1E-02	9.8E-02	9.2E-02	1.0E-01	9.3E-02
6	1.4E-01	9.6E-02	8.7E-02	9.5E-02	9.0E-02	1.0E-01	9.2E-02
7	1.4E-01	9.5E-02	8.3E-02	9.1E-02	8.8E-02	9.9E-02	9.1E-02
8	1.4E-01	9.5E-02	7.9E-02	8.8E-02	8.5E-02	9.7E-02	9.0E-02
9	1.4E-01	9.4E-02	7.5E-02	8.5E-02	8.4E-02	9.7E-02	8.9E-02
10	1.3E-01	9.3E-02	7.2E-02	8.2E-02	8.2E-02	9.6E-02	8.8E-02
20	1.2E-01	8.6E-02	4.6E-02	5.9E-02	6.5E-02	8.7E-02	8.1E-02
30	1.2E-01	8.1E-02	2.9E-02	4.2E-02	5.2E-02	7.9E-02	7.5E-02

TABLE XII-A7-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR IODINE OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.1E-01	2.2E-01	2.5E-01	2.6E-01	2.2E-01	2.3E-01	2.1E-01
2	2.7E-02	1.9E-02	1.9E-02	2.0E-02	2.0E-02	2.0E-02	1.8E-02
3	1.8E-03	1.2E-03	3.5E-03	2.7E-03	1.9E-03	1.4E-03	1.2E-03
4	2.1E-04	1.4E-04	3.0E-03	2.1E-03	9.9E-04	2.7E-04	2.0E-04
5	1.4E-04	9.6E-05	3.1E-03	2.3E-03	1.1E-03	2.5E-04	1.8E-04
6	1.6E-04	1.1E-04	3.1E-03	2.4E-03	1.2E-03	2.9E-04	2.1E-04
7	1.9E-04	1.3E-04	3.1E-03	2.4E-03	1.3E-03	3.4E-04	2.4E-04
8	2.2E-04	1.5E-04	3.0E-03	2.4E-03	1.4E-03	3.7E-04	2.7E-04
9	2.4E-04	1.7E-04	2.9E-03	2.4E-03	1.4E-03	4.0E-04	2.9E-04
10	2.7E-04	1.9E-04	2.8E-03	2.3E-03	1.4E-03	4.3E-04	3.2E-04
20	4.2E-04	3.0E-04	1.8E-03	1.7E-03	1.2E-03	5.6E-04	4.3E-04
30	4.9E-04	3.4E-04	1.1E-03	1.2E-03	9.7E-04	5.6E-04	4.4E-04

TABLE XII-A7-5. INHALATION INTAKE RETENTION IN THYROID (MASS PER UNIT MASS INTAKE) FOR IODINE VAPOUR

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.50E-01	2.5E-01	2.4E-01	2.4E-01	2.5E-01	2.5E-01	2.5E-01
2	2.60E-01	2.7E-01	2.4E-01	2.5E-01	2.6E-01	2.6E-01	2.6E-01
3	2.60E-01	2.6E-01	2.3E-01	2.4E-01	2.5E-01	2.6E-01	2.6E-01
4	2.60E-01	2.6E-01	2.2E-01	2.3E-01	2.4E-01	2.6E-01	2.6E-01
5	2.60E-01	2.6E-01	2.1E-01	2.2E-01	2.4E-01	2.6E-01	2.6E-01
6	2.60E-01	2.6E-01	2.0E-01	2.2E-01	2.3E-01	2.5E-01	2.6E-01
7	2.50E-01	2.6E-01	1.9E-01	2.1E-01	2.3E-01	2.5E-01	2.5E-01
8	2.50E-01	2.5E-01	1.8E-01	2.0E-01	2.2E-01	2.5E-01	2.5E-01
9	2.50E-01	2.5E-01	1.8E-01	2.0E-01	2.2E-01	2.5E-01	2.5E-01
10	2.50E-01	2.5E-01	1.7E-01	1.9E-01	2.1E-01	2.4E-01	2.5E-01

TABLE XII-A7-6. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR IODINE VAPOUR

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.70E-01	5.8E-01	5.9E-01	5.8E-01	5.8E-01	5.8E-01	5.8E-01
2	5.10E-02	5.0E-02	4.5E-02	4.4E-02	5.1E-02	5.1E-02	5.0E-02
3	3.30E-03	3.3E-03	8.2E-03	6.2E-03	4.9E-03	3.5E-03	3.4E-03
4	3.80E-04	3.8E-04	6.9E-03	4.7E-03	2.6E-03	6.8E-04	5.7E-04
5	2.60E-04	2.6E-04	7.2E-03	5.1E-03	2.9E-03	6.4E-04	4.9E-04
6	3.00E-04	3.0E-04	7.3E-03	5.4E-03	3.2E-03	7.5E-04	5.8E-04
7	3.60E-04	3.6E-04	7.2E-03	5.5E-03	3.4E-03	8.5E-04	6.7E-04
8	4.10E-04	4.1E-04	7.0E-03	5.5E-03	3.5E-03	9.5E-04	7.5E-04
9	4.50E-04	4.5E-04	6.8E-03	5.4E-03	3.6E-03	1.0E-03	8.2E-04
10	4.90E-04	4.9E-04	6.5E-03	5.3E-03	3.6E-03	1.1E-03	8.8E-04

TABLE XII-A7-7. INHALATION INTAKE RETENTION IN THYROID (MASS PER UNIT MASS INTAKE) FOR CH_3I: METHYL IODINE VAPOUR

Time after intake [d]	Workers [59]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.0E-01	2.0E-01	1.9E-01	1.9E-01	1.9E-01	2.0E-01	2.0E-01
2	2.1E-01	2.1E-01	1.9E-01	2.0E-01	2.0E-01	2.1E-01	2.1E-01
3	2.1E-01	2.1E-01	1.8E-01	1.9E-01	2.0E-01	2.0E-01	2.0E-01
4	2.0E-01	2.0E-01	1.7E-01	1.8E-01	1.9E-01	2.0E-01	2.0E-01
5	2.0E-01	2.0E-01	1.7E-01	1.7E-01	1.9E-01	2.0E-01	2.0E-01
6	2.0E-01	2.0E-01	1.6E-01	1.7E-01	1.8E-01	2.0E-01	2.0E-01
7	2.0E-01	2.0E-01	1.5E-01	1.6E-01	1.8E-01	2.0E-01	2.0E-01
8	2.0E-01	2.0E-01	1.4E-01	1.6E-01	1.7E-01	1.9E-01	2.0E-01
9	2.0E-01	2.0E-01	1.4E-01	1.5E-01	1.7E-01	1.9E-01	1.9E-01
10	1.9E-01	1.9E-01	1.3E-01	1.5E-01	1.7E-01	1.9E-01	1.9E-01
20	1.8E-01	1.8E-01	8.3E-02	1.0E-01	1.3E-01	1.7E-01	1.8E-01
30	1.7E-01	1.7E-01	5.3E-02	7.4E-02	1.1E-01	1.6E-01	1.6E-01

TABLE XII-A7-8. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR CH_3I: METHYL IODINE VAPOUR

Time after intake [d]	Workers [59]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.5E-01	4.5E-01	4.6E-01	4.6E-01	4.5E-01	4.5E-01	4.5E-01
2	3.7E-02	3.7E-02	3.3E-02	3.3E-02	3.8E-02	3.7E-02	3.7E-02
3	2.4E-03	2.4E-03	6.3E-03	4.8E-03	3.7E-03	2.6E-03	2.5E-03
4	2.9E-04	2.9E-04	5.4E-03	3.7E-03	2.0E-03	5.2E-04	4.4E-04
5	2.0E-04	2.0E-04	5.7E-03	4.0E-03	2.2E-03	5.0E-04	3.9E-04
6	2.4E-04	2.4E-04	5.7E-03	4.2E-03	2.5E-03	5.8E-04	4.6E-04
7	2.8E-04	2.8E-04	5.6E-03	4.3E-03	2.6E-03	6.7E-04	5.2E-04
8	3.2E-04	3.2E-04	5.5E-03	4.3E-03	2.7E-03	7.4E-04	5.8E-04
9	3.5E-04	3.5E-04	5.3E-03	4.2E-03	2.8E-03	8.0E-04	6.4E-04
10	3.9E-04	3.9E-04	5.1E-03	4.1E-03	2.8E-03	8.6E-04	6.9E-04
20	6.2E-04	6.2E-04	3.2E-03	3.0E-03	2.4E-03	1.1E-03	9.3E-04
30	7.2E-04	7.2E-04	2.1E-03	2.1E-03	2.0E-03	1.1E-03	9.6E-04

XII-A8. Caesium

Dosimetric data

TABLE XII-A8-1. CAESIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Caesium	All compounds	F

TABLE XII-A8-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF CAESIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and its yield
Cs-134	2.06 a	9.22E–4	γ (0.60 MeV) 98%, γ (0.80 MeV) 85%
Cs-137	30.0 a	6.33E–5	γ of ^{137m}Ba (0.662 MeV) 85%

Biokinetic data

TABLE XII-A8-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR CESIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	6.0E-01	3.9E-01	4.6E-01	4.6E-01	4.0E-01	4.1E-01	3.7E-01
2	5.1E-01	3.4E-01	3.9E-01	4.0E-01	3.5E-01	3.6E-01	3.3E-01
3	4.7E-01	3.2E-01	3.6E-01	3.6E-01	3.2E-01	3.3E-01	3.0E-01
4	4.5E-01	3.1E-01	3.4E-01	3.3E-01	3.0E-01	3.1E-01	2.9E-01
5	4.4E-01	3.0E-01	3.2E-01	3.2E-01	2.9E-01	3.0E-01	2.8E-01
6	4.3E-01	3.0E-01	3.1E-01	3.0E-01	2.7E-01	2.9E-01	2.8E-01
7	4.2E-01	2.9E-01	2.9E-01	2.8E-01	2.6E-01	2.8E-01	2.7E-01
8	4.2E-01	2.9E-01	2.8E-01	2.7E-01	2.5E-01	2.7E-01	2.7E-01
9	4.1E-01	2.9E-01	2.7E-01	2.5E-01	2.4E-01	2.6E-01	2.7E-01
10	4.1E-01	2.9E-01	2.6E-01	2.4E-01	2.3E-01	2.5E-01	2.6E-01
20	3.8E-01	2.7E-01	1.7E-01	1.4E-01	1.6E-01	2.0E-01	2.4E-01
30	3.6E-01	2.5E-01	1.1E-01	8.3E-02	1.1E-01	1.7E-01	2.3E-01

TABLE XII-A8-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR CESIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	8.9E-03	5.5E-03	8.1E-03	1.1E-02	7.2E-03	7.1E-03	6.3E-03
2	1.1E-02	7.7E-03	1.2E-02	1.5E-02	1.2E-02	1.1E-02	9.0E-03
3	8.6E-03	6.1E-03	1.2E-02	1.5E-02	1.2E-02	1.1E-02	7.3E-03
4	6.7E-03	4.8E-03	1.2E-02	1.4E-02	1.1E-02	9.7E-03	5.7E-03
5	5.4E-03	3.8E-03	1.1E-02	1.4E-02	1.0E-02	8.9E-03	4.6E-03
6	4.4E-03	3.1E-03	1.1E-02	1.3E-02	9.6E-03	8.1E-03	3.8E-03
7	3.7E-03	2.6E-03	1.0E-02	1.2E-02	9.1E-03	7.4E-03	3.2E-03
8	3.2E-03	2.3E-03	9.8E-03	1.2E-02	8.6E-03	6.9E-03	2.8E-03
9	2.9E-03	2.0E-03	9.4E-03	1.1E-02	8.1E-03	6.3E-03	2.4E-03
10	2.6E-03	1.9E-03	9.0E-03	1.0E-02	7.6E-03	5.9E-03	2.2E-03
20	2.0E-03	1.4E-03	5.8E-03	6.1E-03	4.5E-03	3.1E-03	1.5E-03
30	1.8E-03	1.3E-03	3.8E-03	3.6E-03	2.8E-03	2.1E-03	1.4E-03

XII-A9. Radium

Dosimetric data

TABLE XII-A9-1. RADIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Radium	All compounds	M

TABLE XII-A9-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF RADIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Ra-226	1.60E3 a	1.19E–6	α (4.6 MeV) 6%, α (4.8 MeV) 94%, γ (0.19 MeV) 3% + γ of the progenies of ^{222}Rn
Ra-228	5.75 a	3.30E-4	γ of ^{228}Ac (0.34 MeV) 16%, γ (0.91 MeV) 29%, γ (0.96 MeV) 23% + γ of the progenies of ^{220}Rn

Biokinetic data

TABLE XII-A9-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR RADIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.0E-01	3.4E-01	4.0E-01	4.0E-01	3.5E-01	3.6E-01	3.3E-01
2	2.7E-01	2.2E-01	2.6E-01	2.5E-01	2.2E-01	2.3E-01	2.3E-01
3	1.6E-01	1.7E-01	1.9E-01	1.7E-01	1.6E-01	1.7E-01	1.8E-01
4	1.1E-01	1.4E-01	1.7E-01	1.4E-01	1.4E-01	1.4E-01	1.5E-01
5	9.3E-02	1.3E-01	1.5E-01	1.3E-01	1.2E-01	1.3E-01	1.4E-01
6	8.2E-02	1.2E-01	1.5E-01	1.2E-01	1.2E-01	1.2E-01	1.4E-01
7	7.6E-02	1.2E-01	1.4E-01	1.1E-01	1.1E-01	1.2E-01	1.4E-01
8	7.2E-02	1.2E-01	1.4E-01	1.1E-01	1.1E-01	1.1E-01	1.3E-01
9	7.0E-02	1.1E-01	1.4E-01	1.1E-01	1.1E-01	1.1E-01	1.3E-01
10	6.8E-02	1.1E-01	1.3E-01	1.1E-01	1.0E-01	1.1E-01	1.3E-01
20	5.8E-02	9.9E-02	1.2E-01	9.3E-02	9.2E-02	9.6E-02	1.2E-01
30	5.1E-02	8.8E-02	1.1E-01	8.4E-02	8.2E-02	8.7E-02	1.1E-01

TABLE XII-A9-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR RADIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.6E-03	6.6E-04	3.4E-04	5.5E-04	5.3E-04	3.7E-04	1.9E-04
2	3.0E-04	1.3E-04	1.1E-04	1.4E-04	1.3E-04	1.1E-04	6.3E-05
3	2.0E-04	9.3E-05	9.2E-05	1.0E-04	9.6E-05	8.4E-05	5.2E-05
4	1.4E-04	6.9E-05	7.7E-05	8.1E-05	7.5E-05	6.9E-05	4.5E-05
5	1.0E-04	5.3E-05	6.7E-05	6.5E-05	5.9E-05	5.7E-05	3.9E-05
6	7.5E-05	4.2E-05	5.8E-05	5.3E-05	4.7E-05	4.8E-05	3.5E-05
7	5.6E-05	3.4E-05	5.0E-05	4.3E-05	3.9E-05	4.0E-05	3.1E-05
8	4.2E-05	2.9E-05	4.4E-05	3.6E-05	3.3E-05	3.4E-05	2.7E-05
9	3.3E-05	2.5E-05	3.9E-05	3.1E-05	2.8E-05	3.0E-05	2.5E-05
10	2.7E-05	2.2E-05	3.5E-05	2.7E-05	2.4E-05	2.6E-05	2.2E-05
20	1.1E-05	1.5E-05	1.7E-05	1.4E-05	1.3E-05	1.3E-05	1.3E-05
30	9.5E-06	1.3E-05	1.3E-05	1.2E-05	1.2E-05	1.1E-05	1.0E-05

XII-A10. Thorium

Dosimetric data

TABLE XII-A10-1. THORIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Thorium	Oxides and hydroxides	S (Default for public)
	All unspecified compounds	M

TABLE XII-A10-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF THORIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Th-228	1.91 a	9.94E–4	α (5.3 MeV) 27%, α (5.4 MeV) 73% + γ from the progenies of ^{220}Rn
Th-232	1.40E10 a	1.36E–13	α (3.95-4.01 MeV) 100%, γ of ^{228}Ac (0.34 MeV) 16%, γ (0.91 MeV) 29%, γ (0.96 MeV) 23% + same as ^{228}Th

Biokinetic data

TABLE XII-A10-3. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR THORIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.0E-01	3.4E-01	3.9E-01	4.0E-01	3.5E-01	3.6E-01	3.2E-01
2	2.6E-01	2.3E-01	2.4E-01	2.4E-01	2.2E-01	2.2E-01	2.2E-01
3	1.5E-01	1.7E-01	1.6E-01	1.7E-01	1.6E-01	1.6E-01	1.7E-01
4	1.1E-01	1.5E-01	1.3E-01	1.4E-01	1.4E-01	1.4E-01	1.5E-01
5	9.2E-02	1.4E-01	1.2E-01	1.3E-01	1.3E-01	1.3E-01	1.4E-01
6	8.5E-02	1.4E-01	1.2E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
7	8.3E-02	1.4E-01	1.1E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
8	8.1E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
9	8.0E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
10	8.0E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.2E-01	1.3E-01
20	7.5E-02	1.2E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
30	7.2E-02	1.2E-01	9.8E-02	1.1E-01	1.1E-01	1.0E-01	1.1E-01

TABLE XII-A10-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR THORIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-03	9.2E-04	6.8E-04	6.7E-04	6.0E-04	6.1E-04	5.9E-04
2	2.1E-04	2.1E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04
3	1.4E-04	1.3E-04	9.2E-05	9.2E-05	8.6E-05	8.6E-05	8.6E-05
4	1.1E-04	1.1E-04	7.6E-05	7.6E-05	7.2E-05	7.2E-05	7.3E-05
5	9.6E-05	1.0E-04	6.7E-05	6.7E-05	6.4E-05	6.3E-05	6.5E-05
6	8.4E-05	9.1E-05	5.9E-05	6.0E-05	5.7E-05	5.7E-05	5.8E-05
7	7.5E-05	8.3E-05	5.4E-05	5.5E-05	5.2E-05	5.2E-05	5.3E-05
8	6.8E-05	7.7E-05	5.0E-05	5.0E-05	4.8E-05	4.8E-05	5.0E-05
9	6.2E-05	7.3E-05	4.6E-05	4.7E-05	4.5E-05	4.5E-05	4.7E-05
10	5.8E-05	6.9E-05	4.4E-05	4.5E-05	4.3E-05	4.2E-05	4.4E-05
20	3.8E-05	5.3E-05	3.2E-05	3.3E-05	3.2E-05	3.2E-05	3.4E-05
30	3.0E-05	4.6E-05	2.7E-05	2.8E-05	2.8E-05	2.7E-05	2.9E-05

TABLE XII-A10-5. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR THORIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-01	5.3E-02	7.3E-02	7.3E-02	6.0E-02	6.3E-02	5.0E-02
2	1.6E-01	7.7E-02	1.1E-01	1.1E-01	8.7E-02	9.1E-02	7.4E-02
3	7.9E-02	4.0E-02	5.5E-02	5.5E-02	4.6E-02	4.7E-02	3.9E-02
4	3.3E-02	1.8E-02	2.3E-02	2.3E-02	2.0E-02	2.0E-02	1.7E-02
5	1.3E-02	7.5E-03	9.6E-03	9.6E-03	8.2E-03	8.4E-03	7.2E-03
6	5.2E-03	3.4E-03	4.1E-03	4.1E-03	3.6E-03	3.7E-03	3.4E-03
7	2.3E-03	1.9E-03	2.0E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.2E-03	1.3E-03	1.2E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03
9	7.3E-04	1.0E-03	9.3E-04	9.6E-04	9.5E-04	9.4E-04	1.0E-03
10	5.7E-04	9.4E-04	8.1E-04	8.3E-04	8.4E-04	8.3E-04	9.4E-04
20	3.7E-04	6.8E-04	5.6E-04	5.9E-04	6.0E-04	5.9E-04	6.8E-04
30	2.8E-04	5.3E-04	4.3E-04	4.5E-04	4.6E-04	4.5E-04	5.2E-04

TABLE XII-A10-6. INHALATION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR THORIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	4.9E-01	3.4E-01	3.9E-01	4.0E-01	3.5E-01	3.5E-01	3.2E-01
2	2.5E-01	2.2E-01	2.3E-01	2.4E-01	2.2E-01	2.2E-01	2.1E-01
2.75	1.6E-01	1.7E-01	1.5E-01	1.6E-01	1.5E-01	1.5E-01	1.6E-01
3	1.4E-01	1.4E-01	1.2E-01	1.3E-01	1.3E-01	1.2E-01	1.4E-01
4	9.0E-02	1.3E-01	1.1E-01	1.2E-01	1.2E-01	1.1E-01	1.3E-01
5	7.3E-02	1.3E-01	1.0E-01	1.1E-01	1.1E-01	1.1E-01	1.2E-01
6	6.6E-02	1.3E-01	9.9E-02	1.1E-01	1.1E-01	1.1E-01	1.2E-01
7	6.3E-02	1.2E-01	9.7E-02	1.1E-01	1.1E-01	1.1E-01	1.2E-01
8	6.1E-02	1.2E-01	9.6E-02	1.0E-01	1.1E-01	1.0E-01	1.2E-01
9	6.0E-02	1.2E-01	9.5E-02	1.0E-01	1.1E-01	1.0E-01	1.2E-01
10	6.0E-02	1.1E-01	8.8E-02	9.5E-02	9.8E-02	9.5E-02	1.1E-01
20	5.5E-02	1.1E-01	8.2E-02	8.9E-02	9.1E-02	8.8E-02	1.0E-01
30	5.1E-02	3.4E-01	3.9E-01	4.0E-01	3.5E-01	3.5E-01	3.2E-01

TABLE XII-A10-7. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR THORIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.4E-05	1.3E-05	3.9E-05	1.0E-05	8.7E-06	8.8E-06	8.2E-06
2	3.0E-06	3.6E-06	1.1E-05	2.5E-06	2.4E-06	2.4E-06	2.3E-06
3	1.9E-06	2.2E-06	5.7E-06	1.6E-06	1.4E-06	1.5E-06	1.4E-06
4	1.6E-06	1.9E-06	4.6E-06	1.3E-06	1.2E-06	1.2E-06	1.2E-06
5	1.4E-06	1.7E-06	3.8E-06	1.2E-06	1.1E-06	1.1E-06	1.1E-06
6	1.2E-06	1.6E-06	3.3E-06	1.1E-06	1.0E-06	1.0E-06	1.0E-06
7	1.1E-06	1.5E-06	3.0E-06	1.0E-06	9.5E-07	9.4E-07	9.6E-07
8	1.0E-06	1.4E-06	2.7E-06	9.4E-07	9.0E-07	8.9E-07	9.1E-07
9	9.7E-07	1.4E-06	2.4E-06	8.9E-07	8.5E-07	8.5E-07	8.8E-07
10	9.2E-07	1.3E-06	2.3E-06	8.6E-07	8.2E-07	8.1E-07	8.5E-07
20	6.9E-07	1.1E-06	1.5E-06	7.0E-07	6.9E-07	6.7E-07	7.3E-07
30	5.9E-07	1.1E-06	1.2E-06	6.4E-07	6.3E-07	6.1E-07	6.7E-07

TABLE XII-A10-8. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR THORIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.2E-01	5.5E-02	7.7E-02	7.7E-02	6.3E-02	6.6E-02	5.3E-02
2	1.6E-01	8.1E-02	1.1E-01	1.1E-01	9.2E-02	9.6E-02	7.8E-02
3	8.3E-02	4.3E-02	5.8E-02	5.8E-02	4.8E-02	5.0E-02	4.1E-02
4	3.5E-02	1.9E-02	2.5E-02	2.5E-02	2.1E-02	2.2E-02	1.8E-02
5	1.4E-02	8.0E-03	1.0E-02	1.0E-02	8.7E-03	9.0E-03	7.7E-03
6	5.5E-03	3.7E-03	4.4E-03	4.4E-03	3.9E-03	4.0E-03	3.6E-03
7	2.4E-03	2.1E-03	2.2E-03	2.2E-03	2.1E-03	2.1E-03	2.0E-03
8	1.3E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.3E-03	1.4E-03
9	8.2E-04	1.2E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.2E-03
10	6.5E-04	1.1E-03	9.2E-04	9.5E-04	9.7E-04	9.5E-04	1.1E-03
20	4.4E-04	8.2E-04	6.8E-04	7.1E-04	7.3E-04	7.1E-04	8.2E-04
30	3.5E-04	6.6E-04	5.4E-04	5.7E-04	5.9E-04	5.7E-04	6.6E-04

XII-A11. Uranium

Dosimetric data

TABLE XII-A11-1. URANIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Uranium	Most hexavalent compounds, e.g. UF_6 , UO_2F_2 and $UO_2(NO_3)_2$	F
	Less soluble compounds, e.g. UO_3, UF_4, UCl_4 and most other hexavalent compounds	M (Default for public)
	Highly insoluble compounds, e.g. UO_2 and U_3O_8	S

TABLE XII-A11-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF URANIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
U-234	2.44E5 a	7.78E–9	α (4.72 MeV) 27%, α (4.77 MeV) 72%
U-235	7.04E8 a	2.70E–12	α (4.37 MeV) 18%, α (4.40 MeV) 56%, γ (0.144 MeV) 11%, (0.186 MeV) 54%
U-238	4.47E9 a	4.25E–13	α (4.15 MeV) 23%, α (4.20 MeV) 77%

Biokinetic data

TABLE XII-A11-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR URANIUM OF ABSORPTION TYPE F

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.9E-01	1.6E-01	1.1E-01	1.5E-01	1.4E-01	1.2E-01	1.0E-01
2	6.0E-03	5.4E-03	5.3E-03	5.8E-03	5.5E-03	5.4E-03	5.0E-03
3	5.1E-03	4.4E-03	4.6E-03	4.9E-03	4.5E-03	4.6E-03	4.3E-03
4	4.6E-03	4.0E-03	4.2E-03	4.4E-03	4.1E-03	4.1E-03	3.9E-03
5	4.2E-03	3.6E-03	3.9E-03	4.1E-03	3.7E-03	3.8E-03	3.6E-03
6	3.8E-03	3.3E-03	3.6E-03	3.7E-03	3.4E-03	3.5E-03	3.3E-03
7	3.5E-03	3.0E-03	3.3E-03	3.4E-03	3.1E-03	3.2E-03	3.0E-03
8	3.2E-03	2.7E-03	3.1E-03	3.1E-03	2.8E-03	2.9E-03	2.8E-03
9	2.9E-03	2.5E-03	2.8E-03	2.9E-03	2.6E-03	2.7E-03	2.6E-03
10	2.7E-03	2.3E-03	2.6E-03	2.6E-03	2.4E-03	2.5E-03	2.4E-03
20	1.3E-03	1.1E-03	1.3E-03	1.3E-03	1.1E-03	1.2E-03	1.2E-03
30	6.8E-04	5.8E-04	8.1E-04	7.1E-04	6.3E-04	6.9E-04	7.1E-04

TABLE XII-A11-4. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR URANIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.3E-02	1.8E-02	1.5E-02	1.8E-02	1.7E-02	1.5E-02	1.2E-02
2	1.0E-03	1.1E-03	1.1E-03	1.0E-03	1.0E-03	9.8E-04	8.9E-04
3	8.5E-04	9.1E-04	8.8E-04	8.9E-04	8.5E-04	8.1E-04	7.6E-04
4	7.8E-04	8.6E-04	8.2E-04	8.4E-04	8.0E-04	7.7E-04	7.2E-04
5	7.3E-04	8.2E-04	7.7E-04	7.9E-04	7.6E-04	7.3E-04	6.9E-04
6	6.8E-04	7.9E-04	7.3E-04	7.5E-04	7.2E-04	6.9E-04	6.6E-04
7	6.4E-04	7.6E-04	7.0E-04	7.2E-04	6.9E-04	6.6E-04	6.3E-04
8	6.1E-04	7.3E-04	6.6E-04	6.8E-04	6.6E-04	6.3E-04	6.1E-04
9	5.7E-04	7.0E-04	6.3E-04	6.6E-04	6.4E-04	6.1E-04	5.8E-04
10	5.4E-04	6.8E-04	6.0E-04	6.3E-04	6.1E-04	5.8E-04	5.6E-04
20	3.5E-04	5.2E-04	4.2E-04	4.6E-04	4.6E-04	4.3E-04	4.3E-04
30	2.7E-04	4.4E-04	3.4E-04	3.8E-04	3.8E-04	3.5E-04	3.6E-04

TABLE XII-A11-5. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR URANIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.1E-04	4.2E-04	2.5E-03	4.6E-04	4.0E-04	3.6E-04	2.7E-04
2	3.8E-05	3.4E-05	1.9E-04	3.3E-05	3.3E-05	3.1E-05	2.6E-05
3	2.6E-05	2.3E-05	1.3E-04	2.4E-05	2.2E-05	2.1E-05	1.9E-05
4	2.4E-05	2.1E-05	1.1E-04	2.2E-05	2.0E-05	2.0E-05	1.8E-05
5	2.2E-05	2.0E-05	1.1E-04	2.1E-05	1.9E-05	1.9E-05	1.7E-05
6	2.0E-05	2.0E-05	9.9E-05	2.0E-05	1.9E-05	1.8E-05	1.6E-05
7	1.9E-05	1.9E-05	9.2E-05	1.9E-05	1.8E-05	1.7E-05	1.6E-05
8	1.8E-05	1.8E-05	8.6E-05	1.8E-05	1.7E-05	1.6E-05	1.5E-05
9	1.7E-05	1.8E-05	8.1E-05	1.7E-05	1.6E-05	1.6E-05	1.5E-05
10	1.6E-05	1.7E-05	7.6E-05	1.7E-05	1.6E-05	1.5E-05	1.4E-05
20	1.0E-05	1.4E-05	4.5E-05	1.2E-05	1.2E-05	1.1E-05	1.1E-05
30	7.7E-06	1.2E-05	3.2E-05	1.0E-05	1.0E-05	9.7E-06	9.6E-06

TABLE XII-A11-6. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR URANIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.2E-01	5.5E-02	7.6E-02	7.7E-02	6.3E-02	6.6E-02	5.3E-02
2	1.6E-01	8.1E-02	1.1E-01	1.1E-01	9.2E-02	9.6E-02	7.8E-02
3	8.3E-02	4.3E-02	5.7E-02	5.8E-02	4.8E-02	5.0E-02	4.1E-02
4	3.5E-02	1.9E-02	2.4E-02	2.5E-02	2.1E-02	2.2E-02	1.8E-02
5	1.4E-02	7.9E-03	1.0E-02	1.0E-02	8.7E-03	9.0E-03	7.7E-03
6	5.5E-03	3.7E-03	4.4E-03	4.4E-03	3.9E-03	4.0E-03	3.6E-03
7	2.4E-03	2.1E-03	2.2E-03	2.2E-03	2.1E-03	2.1E-03	2.0E-03
8	1.3E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.3E-03	1.4E-03
9	8.1E-04	1.2E-03	1.0E-03	1.1E-03	1.1E-03	1.1E-03	1.2E-03
10	6.4E-04	1.1E-03	9.1E-04	9.4E-04	9.6E-04	9.4E-04	1.1E-03
20	4.4E-04	8.2E-04	6.7E-04	7.0E-04	7.3E-04	7.1E-04	8.2E-04
30	3.5E-04	6.6E-04	5.4E-04	5.7E-04	5.9E-04	5.7E-04	6.6E-04

XII-A12. Neptunium

Dosimetric data

TABLE XII-A12-1. NEPTUNIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Neptunium	All compounds	M

TABLE XII-A12-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF NEPTUNIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Np-237	2.14E6 a	8.87E–10	α (4.79 MeV) 80%, X (0.013-0.017 MeV) 50%, γ (0.086 MeV) 12.6%

Biokinetic data

TABLE XII-A12-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR NEPTUNIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	6.4E-03	5.4E-03	2.6E-03	2.6E-03	3.6E-03	3.7E-03	3.6E-03
2	1.2E-03	1.2E-03	5.5E-04	5.4E-04	8.2E-04	8.3E-04	8.2E-04
3	6.7E-04	6.9E-04	3.1E-04	3.1E-04	4.6E-04	4.6E-04	4.6E-04
4	4.6E-04	5.0E-04	2.3E-04	2.3E-04	3.3E-04	3.3E-04	3.4E-04
5	3.4E-04	3.9E-04	1.7E-04	1.8E-04	2.6E-04	2.6E-04	2.7E-04
6	2.5E-04	3.2E-04	1.4E-04	1.4E-04	2.1E-04	2.1E-04	2.2E-04
7	2.0E-04	2.7E-04	1.2E-04	1.2E-04	1.8E-04	1.7E-04	1.9E-04
8	1.7E-04	2.4E-04	1.0E-04	1.1E-04	1.6E-04	1.5E-04	1.7E-04
9	1.4E-04	2.2E-04	9.3E-05	9.7E-05	1.4E-04	1.4E-04	1.5E-04
10	1.3E-04	2.1E-04	8.6E-05	9.0E-05	1.3E-04	1.3E-04	1.4E-04
20	8.8E-05	1.7E-04	6.7E-05	7.0E-05	1.0E-04	1.0E-04	1.1E-04
30	7.7E-05	1.5E-04	6.0E-05	6.2E-05	9.3E-05	8.9E-05	1.0E-04

TABLE XII-A12-4. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR NEPTUNIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-01	5.3E-02	7.3E-02	7.3E-02	6.0E-02	6.3E-02	5.0E-02
2	1.6E-01	7.7E-02	1.1E-01	1.1E-01	8.7E-02	9.1E-02	7.4E-02
3	7.9E-02	4.0E-02	5.5E-02	5.5E-02	4.6E-02	4.7E-02	3.9E-02
4	3.3E-02	1.8E-02	2.3E-02	2.3E-02	2.0E-02	2.0E-02	1.7E-02
5	1.3E-02	7.5E-03	9.6E-03	9.6E-03	8.2E-03	8.5E-03	7.3E-03
6	5.2E-03	3.4E-03	4.1E-03	4.2E-03	3.6E-03	3.7E-03	3.4E-03
7	2.3E-03	1.9E-03	2.0E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.2E-03	1.3E-03	1.2E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03
9	7.3E-04	1.0E-03	9.3E-04	9.6E-04	9.6E-04	9.4E-04	1.0E-03
10	5.7E-04	9.4E-04	8.1E-04	8.3E-04	8.5E-04	8.3E-04	9.4E-04
20	3.7E-04	6.8E-04	5.6E-04	5.9E-04	6.1E-04	5.9E-04	6.8E-04
30	2.8E-04	5.3E-04	4.3E-04	4.5E-04	4.7E-04	4.5E-04	5.2E-04

XII-A13. Plutonium

Dosimetric data

TABLE XII-A13-1. PLUTONIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Types
Plutonium	Insoluble oxides	S
	All unspecified compounds	M (Default for public)

TABLE XII-A13-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF PLUTONIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Pu-238	87.7 a	2.17E–5	α (5.46 MeV) 28%, (5.50 MeV) 72%
Pu-239	2.41E4 a	7.88E–8	α (5.11 MeV) 11%, (5.14 MeV) 15%, (5.16 MeV) 74%
Pu-240	6.54E3 a	2.90E–7	α (5.12 MeV) 27%, (5.17 MeV) 73%

Biokinetic data

TABLE XII-A13-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR PLUTONIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.5E-04	2.0E-04	2.3E-04	2.2E-04	2.0E-04	2.0E-04	1.9E-04
2	1.2E-04	1.2E-04	1.2E-04	1.2E-04	1.1E-04	1.1E-04	1.1E-04
3	7.5E-05	7.1E-05	7.4E-05	7.3E-05	6.9E-05	7.0E-05	6.9E-05
4	5.2E-05	5.1E-05	5.2E-05	5.2E-05	4.9E-05	4.9E-05	4.9E-05
5	3.8E-05	3.9E-05	3.9E-05	3.9E-05	3.8E-05	3.7E-05	3.8E-05
6	3.0E-05	3.2E-05	3.1E-05	3.2E-05	3.0E-05	3.0E-05	3.1E-05
7	2.4E-05	2.7E-05	2.6E-05	2.7E-05	2.5E-05	2.5E-05	2.6E-05
8	2.0E-05	2.4E-05	2.2E-05	2.3E-05	2.2E-05	2.2E-05	2.3E-05
9	1.7E-05	2.1E-05	1.9E-05	2.0E-05	2.0E-05	2.0E-05	2.1E-05
10	1.5E-05	2.0E-05	1.8E-05	1.9E-05	1.8E-05	1.8E-05	1.9E-05
20	1.0E-05	1.5E-05	1.3E-05	1.4E-05	1.4E-05	1.3E-05	1.5E-05
30	9.5E-06	1.4E-05	1.3E-05	1.3E-05	1.3E-05	1.3E-05	1.4E-05

TABLE XII-A13-4. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR PLUTONIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-01	5.3E-02	7.3E-02	7.3E-02	6.0E-02	6.3E-02	5.0E-02
2	1.6E-01	7.7E-02	1.1E-01	1.1E-01	8.7E-02	9.1E-02	7.4E-02
3	7.9E-02	4.1E-02	5.5E-02	5.5E-02	4.6E-02	4.8E-02	3.9E-02
4	3.3E-02	1.8E-02	2.4E-02	2.3E-02	2.0E-02	2.0E-02	1.7E-02
5	1.3E-02	7.5E-03	9.7E-03	9.7E-03	8.2E-03	8.5E-03	7.3E-03
6	5.3E-03	3.5E-03	4.2E-03	4.2E-03	3.7E-03	3.8E-03	3.4E-03
7	2.3E-03	1.9E-03	2.1E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.2E-03	1.3E-03	1.3E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03
9	7.5E-04	1.1E-03	9.5E-04	9.7E-04	9.7E-04	9.6E-04	1.1E-03
10	5.8E-04	9.6E-04	8.2E-04	8.4E-04	8.6E-04	8.4E-04	9.6E-04
20	3.7E-04	6.9E-04	5.7E-04	5.9E-04	6.1E-04	6.0E-04	6.9E-04
30	2.8E-04	5.3E-04	4.4E-04	4.6E-04	4.7E-04	4.6E-04	5.3E-04

TABLE XII-A13-5. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR PLUTONIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.5E-06	2.0E-06	2.4E-06	2.3E-06	2.0E-06	2.0E-06	2.0E-06
2	1.3E-06	1.2E-06	1.3E-06	1.3E-06	1.2E-06	1.2E-06	1.2E-06
3	8.1E-07	8.2E-07	8.6E-07	8.2E-07	7.8E-07	7.8E-07	7.9E-07
4	5.8E-07	6.2E-07	6.4E-07	6.2E-07	5.9E-07	5.9E-07	6.0E-07
5	4.5E-07	5.2E-07	5.1E-07	5.0E-07	4.9E-07	4.8E-07	5.0E-07
6	3.6E-07	4.5E-07	4.3E-07	4.3E-07	4.2E-07	4.1E-07	4.3E-07
7	3.1E-07	4.1E-07	3.8E-07	3.8E-07	3.7E-07	3.7E-07	3.9E-07
8	2.7E-07	3.8E-07	3.4E-07	3.5E-07	3.4E-07	3.4E-07	3.6E-07
9	2.4E-07	3.6E-07	3.2E-07	3.3E-07	3.2E-07	3.2E-07	3.4E-07
10	2.2E-07	3.4E-07	3.0E-07	3.1E-07	3.1E-07	3.0E-07	3.3E-07
20	1.8E-07	3.1E-07	2.6E-07	2.7E-07	2.7E-07	2.6E-07	2.9E-07
30	1.7E-07	3.0E-07	2.6E-07	2.7E-07	2.7E-07	2.6E-07	2.9E-07

TABLE XII-A13-6. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR PLUTONIUM OF ABSORPTION TYPE S

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.2E-01	5.5E-02	7.7E-02	7.7E-02	6.3E-02	6.6E-02	5.3E-02
2	1.6E-01	8.1E-02	1.1E-01	1.1E-01	9.2E-02	9.6E-02	7.8E-02
3	8.3E-02	4.3E-02	5.8E-02	5.8E-02	4.8E-02	5.0E-02	4.1E-02
4	3.5E-02	1.9E-02	2.5E-02	2.5E-02	2.1E-02	2.2E-02	1.8E-02
5	1.4E-02	8.0E-03	1.0E-02	1.0E-02	8.7E-03	9.0E-03	7.7E-03
6	5.5E-03	3.7E-03	4.5E-03	4.4E-03	3.9E-03	4.0E-03	3.6E-03
7	2.4E-03	2.1E-03	2.2E-03	2.2E-03	2.1E-03	2.1E-03	2.0E-03
8	1.3E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03
9	8.2E-04	1.2E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03	1.2E-03
10	6.5E-04	1.1E-03	9.2E-04	9.5E-04	9.7E-04	9.5E-04	1.1E-03
20	4.4E-04	8.2E-04	6.8E-04	7.1E-04	7.3E-04	7.1E-04	8.2E-04
30	3.5E-04	6.6E-04	5.5E-04	5.7E-04	5.9E-04	5.7E-04	6.6E-04

XII-A14. Americium

Dosimetric data

TABLE XII-A14-1. AMERICIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Americium	All compounds	M

TABLE XII-A14-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF AMERICIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Am-241	4.32E2 a	4.40E–6	α (5.39 MeV) 1%, α (5.44 MeV) 13%, (5.49 MeV) 85%, γ (0.0595 MeV) 36%

Biokinetic data

TABLE XII-A14-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR AMERICIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.8E-03	1.5E-03	1.7E-03	1.7E-03	1.5E-03	1.5E-03	1.5E-03
2	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.1E-04	2.1E-04	2.1E-04
3	1.3E-04	1.4E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04
4	8.8E-05	1.0E-04	9.5E-05	9.6E-05	9.4E-05	9.3E-05	9.7E-05
5	7.1E-05	8.6E-05	7.9E-05	8.1E-05	7.9E-05	7.8E-05	8.2E-05
6	6.2E-05	7.9E-05	7.1E-05	7.3E-05	7.2E-05	7.1E-05	7.5E-05
7	5.7E-05	7.4E-05	6.6E-05	6.9E-05	6.8E-05	6.7E-05	7.1E-05
8	5.4E-05	7.1E-05	6.3E-05	6.5E-05	6.5E-05	6.4E-05	6.8E-05
9	5.1E-05	6.9E-05	6.0E-05	6.3E-05	6.2E-05	6.1E-05	6.5E-05
10	4.8E-05	6.7E-05	5.8E-05	6.0E-05	6.0E-05	5.9E-05	6.3E-05
20	3.3E-05	5.3E-05	4.4E-05	4.6E-05	4.6E-05	4.5E-05	5.0E-05
30	2.6E-05	4.5E-05	3.7E-05	3.8E-05	3.9E-05	3.8E-05	4.2E-05

TABLE XII-A14-4. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR AMERICIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-01	5.3E-02	7.3E-02	7.3E-02	6.0E-02	6.3E-02	5.0E-02
2	1.6E-01	7.7E-02	1.1E-01	1.1E-01	8.7E-02	9.1E-02	7.4E-02
3	7.9E-02	4.1E-02	5.5E-02	5.5E-02	4.6E-02	4.7E-02	3.9E-02
4	3.3E-02	1.8E-02	2.4E-02	2.3E-02	2.0E-02	2.0E-02	1.7E-02
5	1.3E-02	7.5E-03	9.6E-03	9.6E-03	8.2E-03	8.5E-03	7.3E-03
6	5.2E-03	3.4E-03	4.1E-03	4.2E-03	3.6E-03	3.7E-03	3.4E-03
7	2.3E-03	1.9E-03	2.0E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.2E-03	1.3E-03	1.2E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03
9	7.4E-04	1.1E-03	9.4E-04	9.6E-04	9.6E-04	9.5E-04	1.1E-03
10	5.7E-04	9.4E-04	8.1E-04	8.3E-04	8.5E-04	8.3E-04	9.5E-04
20	3.7E-04	6.9E-04	5.7E-04	5.9E-04	6.1E-04	5.9E-04	6.9E-04
30	2.8E-04	5.3E-04	4.3E-04	4.5E-04	4.7E-04	4.6E-04	5.3E-04

XII-A15. Curium

Dosimetric data

TABLE XII-A15-1. CURIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Curium	All compounds	M

TABLE XII-A15-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF CURIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Cm-242	163 d	4.25E–3	α (6.07 MeV) 26%, α (6.11 MeV) 74%
Cm-244	18.1 a	1.05E–4	α (5.76 MeV) 24%, α (5.81 MeV) 76%

Biokinetic data

TABLE XII-A15-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR CURIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.3E-03	1.5E-03	1.7E-03	1.7E-03	1.5E-03	1.5E-03	1.5E-03
2	9.9E-05	2.2E-04	2.2E-04	2.2E-04	2.1E-04	2.1E-04	2.1E-04
3	2.0E-05	1.4E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04	1.3E-04
4	1.5E-05	1.0E-04	9.5E-05	9.6E-05	9.4E-05	9.3E-05	9.7E-05
5	1.4E-05	8.6E-05	7.9E-05	8.1E-05	7.9E-05	7.8E-05	8.2E-05
6	1.4E-05	7.9E-05	7.1E-05	7.3E-05	7.2E-05	7.1E-05	7.5E-05
7	1.4E-05	7.4E-05	6.6E-05	6.9E-05	6.8E-05	6.7E-05	7.1E-05
8	1.3E-05	7.1E-05	6.3E-05	6.5E-05	6.5E-05	6.4E-05	6.8E-05
9	1.3E-05	6.9E-05	6.0E-05	6.3E-05	6.2E-05	6.1E-05	6.5E-05
10	1.3E-05	6.7E-05	5.8E-05	6.0E-05	6.0E-05	5.9E-05	6.3E-05
20	1.2E-05	5.3E-05	4.4E-05	4.6E-05	4.6E-05	4.5E-05	4.9E-05
30	1.0E-05	4.5E-05	3.7E-05	3.8E-05	3.9E-05	3.8E-05	4.2E-05

TABLE XII-A15-4. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR CURIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-01	5.3E-02	7.3E-02	7.3E-02	6.0E-02	6.3E-02	5.0E-02
2	1.6E-01	7.7E-02	1.1E-01	1.1E-01	8.7E-02	9.1E-02	7.4E-02
3	7.9E-02	4.0E-02	5.5E-02	5.5E-02	4.6E-02	4.7E-02	3.9E-02
4	3.3E-02	1.8E-02	2.3E-02	2.3E-02	2.0E-02	2.0E-02	1.7E-02
5	1.3E-02	7.5E-03	9.6E-03	9.6E-03	8.2E-03	8.5E-03	7.3E-03
6	5.2E-03	3.4E-03	4.1E-03	4.2E-03	3.6E-03	3.7E-03	3.4E-03
7	2.3E-03	1.9E-03	2.0E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.2E-03	1.3E-03	1.2E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03
9	7.4E-04	1.1E-03	9.4E-04	9.6E-04	9.6E-04	9.4E-04	1.1E-03
10	5.8E-04	9.4E-04	8.1E-04	8.3E-04	8.5E-04	8.3E-04	9.5E-04
20	3.7E-04	6.9E-04	5.7E-04	5.9E-04	6.1E-04	5.9E-04	6.9E-04
30	2.9E-04	5.3E-04	4.3E-04	4.5E-04	4.7E-04	4.6E-04	5.2E-04

XII-A16. Californium

Dosimetric data

TABLE XII-A16-1. CALIFORNIUM COMPOUNDS AND ABSORPTION TYPES [39]

Element	Compounds	Absorption Type
Californium	All compounds	M

TABLE XII-A16-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF CALIFORNIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Cf-252	2.64 a	7.19E-4	fission n^0 (2.16 MeV mean) 12%, fission γ (0.88 MeV mean) 27%, fission γ (0.96 MeV mean) 25%, α (6.08 MeV) 15%, α (6.12 MeV) 82%

TABLE XII-A16-3. INHALATION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR CALIFORNIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.3E-03	1.1E-03	1.2E-03	1.2E-03	1.1E-03	1.1E-03	1.1E-03
2	9.9E-05	1.2E-04	1.1E-04	1.1E-04	1.2E-04	1.2E-04	1.2E-04
3	2.0E-05	3.5E-05	2.9E-05	3.0E-05	3.1E-05	3.0E-05	3.4E-05
4	1.5E-05	2.9E-05	2.3E-05	2.5E-05	2.5E-05	2.5E-05	2.8E-05
5	1.4E-05	2.8E-05	2.2E-05	2.4E-05	2.5E-05	2.4E-05	2.7E-05
6	1.4E-05	2.8E-05	2.2E-05	2.4E-05	2.4E-05	2.4E-05	2.7E-05
7	1.4E-05	2.7E-05	2.2E-05	2.4E-05	2.4E-05	2.3E-05	2.6E-05
8	1.3E-05	2.7E-05	2.1E-05	2.3E-05	2.4E-05	2.3E-05	2.6E-05
9	1.3E-05	2.7E-05	2.1E-05	2.3E-05	2.3E-05	2.3E-05	2.6E-05
10	1.3E-05	2.6E-05	2.1E-05	2.3E-05	2.3E-05	2.2E-05	2.5E-05
20	1.2E-05	2.3E-05	1.8E-05	2.0E-05	2.0E-05	2.0E-05	2.2E-05
30	1.0E-05	2.1E-05	1.6E-05	1.8E-05	1.8E-05	1.7E-05	2.0E-05

TABLE XII-A16-4. INHALATION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR CALIFORNIUM OF ABSORPTION TYPE M

Time after intake [d]	Workers, AMAD 5 μm [54]	Members of the public, AMAD 1 μm [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.1E-01	5.3E-02	7.3E-02	7.3E-02	6.0E-02	6.3E-02	5.1E-02
2	1.6E-01	7.7E-02	1.1E-01	1.1E-01	8.7E-02	9.1E-02	7.4E-02
3	7.9E-02	4.1E-02	5.5E-02	5.5E-02	4.6E-02	4.8E-02	3.9E-02
4	3.3E-02	1.8E-02	2.4E-02	2.3E-02	2.0E-02	2.0E-02	1.7E-02
5	1.3E-02	7.5E-03	9.7E-03	9.6E-03	8.2E-03	8.5E-03	7.3E-03
6	5.2E-03	3.5E-03	4.2E-03	4.2E-03	3.7E-03	3.7E-03	3.4E-03
7	2.3E-03	1.9E-03	2.1E-03	2.1E-03	1.9E-03	1.9E-03	1.9E-03
8	1.2E-03	1.3E-03	1.3E-03	1.3E-03	1.2E-03	1.2E-03	1.3E-03
9	7.4E-04	1.1E-03	9.5E-04	9.7E-04	9.7E-04	9.6E-04	1.1E-03
10	5.8E-04	9.6E-04	8.2E-04	8.4E-04	8.6E-04	8.4E-04	9.6E-04
20	3.7E-04	6.9E-04	5.7E-04	6.0E-04	6.2E-04	6.0E-04	6.9E-04
30	2.9E-04	5.3E-04	4.4E-04	4.6E-04	4.7E-04	4.6E-04	5.3E-04

Part XII-B
Data for evaluation the doses of internal exposurein case of inhalation intake of radionuclides

XII-B1. Data for evaluation of the committed effective doses of internal exposure in case of inhalation intake of radionuclides

TABLE XII-B1-1. INHALATION: COMMITTED EFFECTIVE DOSE PER UNIT INTAKE $e_W^{Inh}(\tau)$ FOR WORKERS [Sv×Bq^{-1}] [39]

Radio-nuclide	Sub-stance*	e_W^{Inh}	Radio-nuclide	Sub-stance	e_W^{Inh}	Radio-nuclide	Sub-stance	e_W^{Inh}
H-3	OBT	4.1E-11	Ru-106	S	3.5E-08	U-234	M	2.1E-06
H-3	Elem	1.8E-15	I-125	CH_3I	1.1E-08	U-234	S	6.8E-06
H-3	HTO	1.8E-11	I-125	Elem	1.4E-08	U-235	F	6.0E-07
Fe-59	F	3.0E-09	I-125	F	7.3E-09	U-235	M	1.8E-06
Fe-59	M	3.2E-09	I-131	CH_3I	1.5E-08	U-235	S	6.1E-06
Co-57	M	3.9E-10	I-131	Elem	2.0E-08	U-238	F	5.8E-07
Co-57	S	6.0E-10	I-131	F	1.1E-08	U-238	M	1.6E-06
Co-58	M	1.4E-09	I-133	CH_3I	3.1E-09	U-238	S	5.7E-06
Co-58	S	1.7E-09	I-133	Elem	4.0E-09	Np-237	M	1.5E-05
Co-60	M	7.1E-09	I-133	F	2.1E-09	Pu-238	M	3.0E-05
Co-60	S	1.7E-08	Cs-134	F	9.6E-09	Pu-238	S	1.1E-05
Sr-85	F	5.6E-10	Cs-137	F	6.7E-09	Pu-239	M	3.2E-05
Sr-85	S	6.4E-10	Ra-226	M	2.2E-06	Pu-239	S	8.3E-06
Sr-89	F	1.4E-09	Ra-228	M	1.7E-06	Pu-240	M	3.2E-05
Sr-89	S	5.6E-09	Th-228	M	2.2E-05	Pu-240	S	8.3E-06
Sr-90	F	3.0E-08	Th-228	S	2.5E-05	Am-241	M	2.7E-05
Sr-90	S	7.7E-08	Th-232	M	2.9E-05	Cm-242	M	3.7E-06
Ru-106	F	9.8E-09	Th-232	S	1.2E-05	Cm-244	M	1.7E-05
Ru-106	M	1.7E-08	U-234	F	6.4E-07	Cf-252	M	1.3E-05

Remarks: * - F, M and S: respectively aerosol of Types F, M and S with AMAD 5 μm; Elem – elementary.

TABLE XII-B1-2. INHALATION: COMMITTED EFFECTIVE DOSE PER UNIT INTAKE $e_P^{Inh}(g,\tau)$ FOR MEMBERS OF THE PUBLIC (Sv×Bq^{-1}] [39]

Radionuclide	Substance*	Age *(g)* of the member of the public					
		Adult	0.25 a	1 a	5 a	10 a	15 a
H-3	HTO	1.8E-11	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11
H-3	Elem	1.8E-15	6.4E-15	4.8E-15	3.1E-15	2.3E-15	1.8E-15
H-3	OBT	4.1E-11	1.1E-10	1.1E-10	7.0E-11	5.5E-11	4.1E-11
Fe-59	F	2.2E-09	2.1E-08	1.3E-08	7.1E-09	4.2E-09	2.6E-09
Fe-59	M	3.7E-09	1.8E-08	1.3E-08	7.9E-09	5.5E-09	4.6E-09
Co-57	M	5.5E-10	2.8E-09	2.2E-09	1.3E-09	8.5E-10	6.7E-10
Co-57	S	1.0E-09	4.4E-09	3.7E-09	2.3E-09	1.5E-09	1.2E-09
Co-58	M	1.6E-09	7.3E-09	6.5E-09	3.5E-09	2.4E-09	2.0E-09
Co-58	S	2.1E-09	9.0E-09	7.5E-09	4.5E-09	3.1E-09	2.6E-09
Co-60	M	1.0E-08	4.2E-08	3.4E-08	2.1E-08	1.5E-08	1.2E-08
Co-60	S	3.1E-08	9.2E-08	8.6E-08	5.9E-08	4.0E-08	3.4E-08
Sr-85	F	3.8E-10	4.4E-09	2.3E-09	1.1E-09	9.6E-10	8.3E-10
Sr-85	S	8.1E-10	4.4E-09	3.7E-09	2.2E-09	1.3E-09	1.0E-09
Sr-89	F	1.0E-09	1.5E-08	7.3E-09	3.2E-09	2.3E-09	1.7E-09
Sr-89	S	7.9E-09	3.9E-08	3.0E-08	1.7E-08	1.2E-08	9.3E-09
Sr-90	F	2.4E-08	1.3E-07	5.2E-08	3.1E-08	4.1E-08	5.3E-08
Sr-90	S	1.6E-07	4.2E-07	4.0E-07	2.7E-07	1.8E-07	1.6E-07

Radionuclide	Substance*	Age *(g)* of the member of the public					
		Adult	0.25 a	1 a	5 a	10 a	15 a
Ru-106	F	7.9E-09	7.2E-08	5.4E-08	2.6E-08	1.6E-08	9.2E-09
Ru-106	M	2.8E-08	1.4E-07	1.1E-07	6.4E-08	4.1E-08	3.1E-08
Ru-106	S	6.6E-08	2.6E-07	2.3E-07	1.4E-07	9.1E-08	7.1E-08
I-125	CH_3I	1.1E-08	3.7E-08	4.0E-08	2.9E-08	2.2E-08	1.6E-08
I-125	Elem	1.4E-08	4.7E-08	5.2E-08	3.7E-08	2.8E-08	2.0E-08
I-125	F	5.1E-09	2.0E-08	2.3E-08	1.5E-08	1.1E-08	7.2E-09
I-131	CH_3I	1.5E-08	1.3E-07	1.3E-07	7.4E-08	3.7E-08	2.4E-08
I-131	Elem	2.0E-08	1.7E-07	1.6E-07	9.4E-08	4.8E-08	3.1E-08
I-131	F	7.4E-09	7.2E-08	7.2E-08	3.7E-08	1.9E-08	1.1E-08
I-133	CH_3I	3.1E-09	3.5E-08	3.2E-08	1.7E-08	7.6E-09	4.9E-09
I-133	Elem	4.0E-09	4.5E-08	4.1E-08	2.1E-08	9.7E-09	6.3E-09
I-133	F	1.5E-09	1.9E-08	1.8E-08	8.3E-09	3.8E-09	2.2E-09
Cs-134	F	6.6E-09	1.1E-08	7.3E-09	5.2E-09	5.3E-09	6.3E-09
Cs-137	F	4.6E-09	8.8E-09	5.4E-09	3.6E-09	3.7E-09	4.4E-09
Ra-226	M	3.5E-06	1.5E-05	1.1E-05	7.0E-06	4.9E-06	4.5E-06
Ra-228	M	2.6E-06	1.5E-05	1.0E-05	6.3E-06	4.6E-06	4.4E-06
Th-228	M	3.2E-05	1.3E-04	1.1E-04	6.8E-05	4.6E-05	3.9E-05
Th-228	S	4.0E-05	1.6E-04	1.3E-04	8.2E-05	5.5E-05	4.7E-05
Th-232	M	4.5E-05	8.3E-05	8.1E-05	6.3E-05	5.0E-05	4.7E-05
Th-232	S	2.5E-05	5.4E-05	5.0E-05	3.7E-05	2.6E-05	2.5E-05
U-234	F	5.6E-07	2.1E-06	1.4E-06	9.0E-07	8.0E-07	8.2E-07
U-234	M	3.5E-06	1.5E-05	1.1E-05	7.0E-06	4.8E-06	4.2E-06
U-234	S	9.4E-06	3.3E-05	2.9E-05	1.9E-05	1.2E-05	1.0E-05
U-235	F	5.2E-07	2.0E-06	1.3E-06	8.5E-07	7.5E-07	7.7E-07
U-235	M	3.1E-06	1.3E-05	1.0E-05	6.3E-06	4.3E-06	3.7E-06
U-235	S	8.5E-06	3.0E-05	2.6E-05	1.7E-05	1.1E-05	9.2E-06
U-238	F	5.0E-07	1.9E-06	1.3E-06	8.2E-07	7.3E-07	7.4E-07
U-238	M	2.9E-06	1.2E-05	9.4E-06	5.9E-06	4.0E-06	3.4E-06
U-238	S	8.0E-06	2.9E-05	2.5E-05	1.6E-05	1.0E-05	8.7E-06
Np-237	M	2.3E-05	4.4E-05	4.0E-05	2.8E-05	2.2E-05	2.2E-05
Pu-238	M	4.6E-05	7.8E-05	7.4E-05	5.6E-05	4.4E-05	4.3E-05
Pu-238	S	1.6E-05	4.5E-05	4.0E-05	2.7E-05	1.9E-05	1.7E-05
Pu-239	M	5.0E-05	8.0E-05	7.7E-05	6.0E-05	4.8E-05	4.7E-05
Pu-239	S	1.6E-05	4.3E-05	3.9E-05	2.7E-05	1.9E-05	1.7E-05
Pu-240	M	5.0E-05	8.0E-05	7.7E-05	6.0E-05	4.8E-05	4.7E-05
Pu-240	S	1.6E-05	4.3E-05	3.9E-05	2.7E-05	1.9E-05	1.7E-05
Am-241	M	4.2E-05	7.3E-05	6.9E-05	5.1E-05	4.0E-05	4.0E-05
Cm-242	M	5.2E-06	2.2E-05	1.8E-05	1.1E-05	7.3E-06	6.4E-06
Cm-244	M	2.7E-05	6.2E-05	5.7E-05	3.7E-05	2.7E-05	2.6E-05
Cf-252	M	2.0E-05	9.7E-05	8.7E-05	5.6E-05	3.2E-05	2.2E-05

Remarks: * - F, M and S: respectively aerosol of Types F, M and S with AMAD 1 μm; Elem – elementary.

XII-B2. Data for evaluation the RBE-weighted absorbed doses to organs and tissues of workers from inhalation intake of radionuclides

TABLE XII-B2-1. INHALATION: COMMITTED RBE-WEIGHTED ABSORBED DOSE TO THE OFFSPRING PER UNIT INTAKE OF FEMALE WORKER*, $Ad^{Inh}_{W,offspring}(\Delta)$,[Gy-Eq×Bq^{-1}]

Radio-nuclide	Sub-stance	$Ad^{Inh}_{W,offspri}$	Radio-nuclide	Sub-stance**	$Ad^{Inh}_{W,offspri}$	Radio-nuclide	Sub-stance**	$Ad^{Inh}_{W,offsp}$
H-3	OBT	7.7E-11	I-125	CH_3I	1.4E-08	U-234	M	2.5E-08
H-3	Elem	3.6E-15	I-125	Elem	1.7E-08	U-234	S	8.0E-10
H-3	HTO	3.6E-11	I-125	F	9.3E-09	U-235	F	1.1E-07
Fe-59	F	2.9E-09	I-131	CH_3I	4.5E-08	U-235	M	2.3E-08

Fe-59	M	9.5E-10	I-131	Elem	5.5E-08	U-235	S	7.5E-10
Co-57	M	8.9E-11	I-131	F	2.9E-08	U-238	F	1.1E-07
Co-57	S	5.9E-11	I-133	CH_3I	9.1E-09	U-238	M	2.2E-08
Co-58	M	3.8E-10	I-133	Elem	1.2E-08	U-238	S	7.0E-10
Co-58	S	3.2E-10	I-133	F	4.4E-09	Np-237	M	3.0E-07
Co-60	M	1.7E-09	Cs-134	F	5.4E-09	Pu-238	M	7.5E-07
Co-60	S	1.1E-09	Cs-137	F	3.5E-09	Pu-238	S	9.0E-09
Sr-89	F	1.2E-08	Ra-226	M	1.3E-07	Pu-239	M	8.0E-07
Sr-89	S	2.8E-10	Ra-228	M	2.1E-07	Pu-239	S	9.5E-09
Sr-90	F	4.6E-08	Th-228	M	7.5E-07	Pu-240	M	8.0E-07
Sr-90	S	1.0E-09	Th-228	S	1.2E-08	Pu-240	S	9.5E-09
Ru-106	F	3.6E-09	Th-232	M	8.0E-07	Am-241	M	1.5E-07
Ru-106	M	8.1E-10	Th-232	S	1.2E-08	Cm-242	M	2.3E-08
Ru-106	S	3.4E-10	U-234	F	1.3E-07	Cm-244	M	1.2E-07

Remarks: * a) For details of RBE-weighted absorbed dose estimation see Introduction to Appendix XII;
b) F, M and S: respectively aerosol of Types F, M and S with AMAD 5 μm; Elem – elementary.

TABLE XII-B2-2. COMMITTED RBE-WEIGHTED ABSORBED DOSE PER UNIT INTAKE $Ad_{W,T}^{Inh}(\Delta)$ DELIVERED IN ORGAN OR TISSUE OF WORKER OVER 30 DAYS AFTER ACUTE INHALATION INTAKE* [Gy-Eq×Bq^{-1}]

Radio-nuclide	Sub-stance	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
H-3	OBT	2.1E-11	2.1E-11	2.1E-11	0
H-3	Elem	1.5E-15	1.5E-15	1.5E-15	0
H-3	HTO	1.5E-11	1.5E-11	1.5E-11	0
Fe-59	F	7.7E-10	1.8E-09	1.8E-09	0
Fe-59	M	2.5E-09	6.1E-10	2.3E-09	0
Co-57	M	4.8E-10	3.3E-11	3.7E-10	0
Co-57	S	5.6E-10	3.0E-11	4.0E-10	0
Co-58	M	1.4E-09	2.2E-10	1.1E-09	0
Co-58	S	1.6E-09	2.1E-10	1.2E-09	0
Co-60	M	3.8E-09	5.6E-10	2.9E-09	0
Co-60	S	4.5E-09	5.4E-10	3.1E-09	0
Sr-85	F	1.4E-10	3.6E-10	4.1E-10	0
Sr-85	S	7.9E-10	1.2E-10	5.7E-10	0
Sr-89	F	2.0E-10	2.3E-09	3.8E-09	0
Sr-89	S	8.8E-09	3.1E-11	7.8E-09	0
Sr-90	F	3.5E-10	4.6E-09	3.8E-09	0
Sr-90	S	1.8E-08	6.2E-11	6.7E-09	0
Ru-106	F	1.4E-09	1.4E-09	1.2E-08	0
Ru-106	M	2.2E-08	3.0E-10	1.8E-08	0
Ru-106	S	2.6E-08	1.5E-10	1.9E-08	0
I-125	CH_3I	1.1E-11	9.4E-12	9.9E-12	8.8E-08
I-125	Elem	1.5E-11	1.2E-11	1.5E-11	1.1E-07
I-125	F	8.3E-12	6.8E-12	8.7E-12	6.0E-08
I-131	CH_3I	6.8E-11	6.7E-11	3.7E-11	5.8E-08
I-131	Elem	9.1E-11	8.8E-11	6.1E-11	7.4E-08
I-131	F	5.5E-11	5.2E-11	3.8E-11	4.0E-08
I-133	CH_3I	3.2E-11	3.3E-11	3.0E-11	6.0E-08
I-133	Elem	4.5E-11	4.4E-11	5.3E-11	7.6E-08
I-133	F	3.1E-11	2.9E-11	3.4E-11	4.0E-08
Cs-134	F	1.7E-09	1.8E-09	2.1E-09	0
Cs-136	F	1.1E-09	1.2E-09	1.4E-09	0

Radio-nuclide	Sub-stance	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
Cs-137	F	1.1E-09	1.1E-09	1.4E-09	0
Ra-226	M	5.3E-07	4.3E-09	0	0
Ra-228	M	3.9E-08	3.9E-10	0	0
Th-228	M	2.7E-06	3.9E-08	0	0
Th-228	S	3.3E-06	5.8E-10	0	0
Th-232	M	4.6E-07	1.2E-08	0	0
Th-232	S	5.3E-07	1.7E-10	0	0
U-234	F	3.9E-09	1.2E-08	0	0
U-234	M	5.3E-07	1.7E-09	0	0
U-234	S	6.0E-07	5.1E-11	0	0
U-235	F	3.4E-09	1.1E-08	0	0
U-235	M	4.9E-07	1.6E-09	0	0
U-235	S	5.6E-07	5.1E-11	0	0
U-238	F	3.3E-09	1.0E-08	0	0
U-238	M	4.6E-07	1.5E-09	0	0
U-238	S	5.3E-07	4.5E-11	0	0
Np-237	M	5.3E-07	1.0E-08	0	0
Pu-238	M	6.0E-07	1.4E-08	0	0
Pu-238	S	7.0E-07	1.6E-10	0	0
Pu-239, Pu-240	M	5.6E-07	1.3E-08	0	0
Pu-239, Pu-240	S	6.7E-07	1.5E-10	0	0
Am-241	M	6.0E-07	7.4E-09	0	0
Cm-242	M	6.3E-07	7.7E-09	0	0
Cm-244	M	6.3E-07	7.8E-09	0	0
Cf-252	M	1.3E-06	3.3E-08	0	0

Remarks: * a) For details of RBE-weighted absorbed dose estimation see Introduction to Appendix XII;
b) F, M and S: respectively aerosol of Types F, M and S with AMAD 5 μm; Elem – elementary;
c) Lung – Alveolar region of Respiratory system (AI).

XII-B3. Data for evaluation the RBE-weighted absorbed doses to organs and tissues of members of the public from inhalation intake of radionuclides

TABLE XII-B3-1. COMMITTED RBE-WEIGHTED ABSORBED DOSE PER UNIT INTAKE $Ad_{P,T}^{Inh}(g,\Delta)$ DELIVERED IN ORGAN OR TISSUE OF MEMBER OF THE PUBLIC OVER 30 DAYS AFTER ACUTE INHALATION INTAKE* [Gy-Eq×Bq^{-1}]

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
H-3	OBT	Adults	2.1E-11	2.1E-11	2.1E-11	0
H-3	OBT	0.25	1.0E-10	1.0E-10	1.0E-10	0
H-3	OBT	1	8.9E-11	8.9E-11	8.9E-11	0
H-3	OBT	5	5.1E-11	5.1E-11	5.1E-11	0
H-3	OBT	10	3.5E-11	3.5E-11	3.5E-11	0
H-3	OBT	15	2.3E-11	2.3E-11	2.3E-11	0
H-3	Elem	Adults	1.5E-15	1.5E-15	1.5E-15	0
H-3	Elem	0.25	6.3E-15	6.3E-15	6.3E-15	0
H-3	Elem	1	4.7E-15	4.7E-15	4.7E-15	0
H-3	Elem	5	2.9E-15	2.9E-15	2.9E-15	0

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
H-3	Elem	10	2.1E-15	2.1E-15	2.1E-15	0
H-3	Elem	15	1.6E-15	1.6E-15	1.6E-15	0
H-3	HTO	Adults	1.5E-11	1.5E-11	1.5E-11	0
H-3	HTO	0.25	6.3E-11	6.3E-11	6.3E-11	0
H-3	HTO	1	4.7E-11	4.7E-11	4.7E-11	0
H-3	HTO	5	2.9E-11	2.9E-11	2.9E-11	0
H-3	HTO	10	2.1E-11	2.1E-11	2.1E-11	0
H-3	HTO	15	1.6E-11	1.6E-11	1.6E-11	0
Fe-59	F	Adults	6.4E-10	1.5E-09	1.1E-09	0
Fe-59	F	0.25	5.6E-09	2.2E-08	8.8E-09	0
Fe-59	F	1	3.5E-09	1.1E-08	7.5E-09	0
Fe-59	F	5	1.8E-09	5.6E-09	3.6E-09	0
Fe-59	F	10	1.2E-09	3.2E-09	2.3E-09	0
Fe-59	F	15	7.8E-10	1.9E-09	1.3E-09	0
Fe-59	M	Adults	5.1E-09	5.5E-10	1.3E-09	0
Fe-59	M	0.25	3.6E-08	6.5E-09	1.4E-08	0
Fe-59	M	1	2.6E-08	3.0E-09	1.0E-08	0
Fe-59	M	5	1.4E-08	1.6E-09	4.7E-09	0
Fe-59	M	10	8.7E-09	1.0E-09	2.9E-09	0
Fe-59	M	15	6.2E-09	6.5E-10	1.5E-09	0
Co-57	M	Adults	1.0E-09	3.8E-11	2.0E-10	0
Co-57	M	0.25	7.4E-09	1.8E-10	2.5E-09	0
Co-57	M	1	5.3E-09	1.3E-10	1.8E-09	0
Co-57	M	5	2.8E-09	7.6E-11	7.8E-10	0
Co-57	M	10	1.7E-09	5.6E-11	4.9E-10	0
Co-57	M	15	1.2E-09	4.3E-11	2.5E-10	0
Co-57	S	Adults	1.2E-09	3.8E-11	2.2E-10	0
Co-57	S	0.25	8.8E-09	1.3E-10	3.0E-09	0
Co-57	S	1	6.3E-09	1.1E-10	2.0E-09	0
Co-57	S	5	3.4E-09	7.0E-11	8.7E-10	0
Co-57	S	10	2.0E-09	5.3E-11	5.4E-10	0
Co-57	S	15	1.4E-09	4.2E-11	2.7E-10	0
Co-58	M	Adults	2.8E-09	2.6E-10	6.4E-10	0
Co-58	M	0.25	1.6E-08	1.1E-09	6.2E-09	0
Co-58	M	1	1.2E-08	8.0E-10	4.7E-09	0
Co-58	M	5	6.9E-09	4.9E-10	2.2E-09	0
Co-58	M	10	4.4E-09	3.7E-10	1.4E-09	0
Co-58	M	15	3.4E-09	2.8E-10	7.6E-10	0
Co-58	S	Adults	3.2E-09	2.7E-10	6.9E-10	0
Co-58	S	0.25	1.9E-08	9.3E-10	7.4E-09	0
Co-58	S	1	1.4E-08	7.6E-10	5.2E-09	0
Co-58	S	5	8.0E-09	4.9E-10	2.4E-09	0
Co-58	S	10	5.2E-09	3.6E-10	1.6E-09	0
Co-58	S	15	4.0E-09	2.9E-10	8.3E-10	0
Co-60	M	Adults	7.8E-09	6.9E-10	1.7E-09	0
Co-60	M	0.25	4.7E-08	2.8E-09	1.6E-08	0
Co-60	M	1	3.5E-08	2.1E-09	1.2E-08	0

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
Co-60	M	5	2.0E-08	1.3E-09	5.8E-09	0
Co-60	M	10	1.3E-08	9.7E-10	3.7E-09	0
Co-60	M	15	9.7E-09	7.5E-10	2.0E-09	0
Co-60	S	Adults	9.2E-09	7.1E-10	1.8E-09	0
Co-60	S	0.25	5.5E-08	2.5E-09	1.9E-08	0
Co-60	S	1	4.1E-08	2.1E-09	1.3E-08	0
Co-60	S	5	2.3E-08	1.3E-09	6.3E-09	0
Co-60	S	10	1.5E-08	9.6E-10	4.1E-09	0
Co-60	S	15	1.1E-08	7.7E-10	2.2E-09	0
Sr-85	F	Adults	1.1E-10	2.8E-10	2.6E-10	0
Sr-85	F	0.25	1.4E-09	3.4E-09	1.9E-09	0
Sr-85	F	1	7.0E-10	1.4E-09	1.5E-09	0
Sr-85	F	5	3.2E-10	6.9E-10	7.3E-10	0
Sr-85	F	10	2.5E-10	6.7E-10	5.2E-10	0
Sr-85	F	15	2.0E-10	6.3E-10	3.2E-10	0
Sr-85	S	Adults	1.6E-09	1.5E-10	3.2E-10	0
Sr-85	S	0.25	8.4E-09	5.6E-10	3.2E-09	0
Sr-85	S	1	6.5E-09	4.3E-10	2.3E-09	0
Sr-85	S	5	3.8E-09	2.7E-10	1.1E-09	0
Sr-85	S	10	2.5E-09	2.0E-10	7.1E-10	0
Sr-85	S	15	2.1E-09	1.6E-10	3.8E-10	0
Sr-89	F	Adults	1.6E-10	1.8E-09	2.2E-09	0
Sr-89	F	0.25	1.4E-09	4.1E-08	1.8E-08	0
Sr-89	F	1	1.2E-09	1.3E-08	1.8E-08	0
Sr-89	F	5	5.6E-10	5.5E-09	7.9E-09	0
Sr-89	F	10	2.9E-10	4.7E-09	4.3E-09	0
Sr-89	F	15	1.3E-10	3.8E-09	1.8E-09	0
Sr-89	S	Adults	1.9E-08	1.8E-11	4.1E-09	0
Sr-89	S	0.25	1.7E-07	7.8E-10	6.4E-08	0
Sr-89	S	1	1.2E-07	1.4E-10	4.1E-08	0
Sr-89	S	5	6.0E-08	5.6E-11	1.7E-08	0
Sr-89	S	10	3.5E-08	4.8E-11	1.0E-08	0
Sr-89	S	15	2.3E-08	3.6E-11	5.0E-09	0
Sr-90	F	Adults	2.8E-10	3.6E-09	2.4E-09	0
Sr-90	F	0.25	2.4E-09	8.3E-08	1.9E-08	0
Sr-90	F	1	2.1E-09	2.6E-08	2.0E-08	0
Sr-90	F	5	9.5E-10	1.1E-08	8.7E-09	0
Sr-90	F	10	4.9E-10	9.3E-09	4.7E-09	0
Sr-90	F	15	2.2E-10	7.8E-09	1.9E-09	0
Sr-90	S	Adults	4.0E-08	3.6E-11	3.9E-09	0
Sr-90	S	0.25	3.5E-07	1.6E-09	5.7E-08	0
Sr-90	S	1	2.4E-07	2.9E-10	3.7E-08	0
Sr-90	S	5	1.2E-07	1.1E-10	1.6E-08	0
Sr-90	S	10	7.3E-08	9.8E-11	9.6E-09	0
Sr-90	S	15	4.7E-08	7.6E-11	4.8E-09	0
Ru-106	F	Adults	1.2E-09	1.2E-09	6.7E-09	0
Ru-106	F	0.25	1.4E-08	1.4E-08	9.6E-08	0

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
Ru-106	F	1	9.3E-09	9.2E-09	6.4E-08	0
Ru-106	F	5	4.2E-09	4.2E-09	2.7E-08	0
Ru-106	F	10	2.5E-09	2.5E-09	1.6E-08	0
Ru-106	F	15	1.5E-09	1.4E-09	8.0E-09	0
Ru-106	M	Adults	4.7E-08	2.7E-10	9.9E-09	0
Ru-106	M	0.25	4.1E-07	3.4E-09	1.4E-07	0
Ru-106	M	1	2.9E-07	1.8E-09	9.7E-08	0
Ru-106	M	5	1.5E-07	8.3E-10	4.1E-08	0
Ru-106	M	10	8.6E-08	5.1E-10	2.5E-08	0
Ru-106	M	15	5.6E-08	3.1E-10	1.2E-08	0
Ru-106	S	Adults	5.6E-08	7.7E-11	1.1E-08	0
Ru-106	S	0.25	4.9E-07	5.5E-10	1.6E-07	0
Ru-106	S	1	3.4E-07	3.0E-10	1.0E-07	0
Ru-106	S	5	1.7E-07	1.6E-10	4.4E-08	0
Ru-106	S	10	1.0E-07	1.1E-10	2.7E-08	0
Ru-106	S	15	6.6E-08	8.5E-11	1.3E-08	0
I-125	CH_3I	Adults	1.1E-11	9.4E-12	9.9E-12	8.8E-08
I-125	CH_3I	0.25	1.8E-10	7.8E-11	3.7E-10	5.9E-07
I-125	CH_3I	1	1.3E-10	5.2E-11	2.2E-10	6.0E-07
I-125	CH_3I	5	6.0E-11	2.7E-11	8.7E-11	3.7E-07
I-125	CH_3I	10	3.2E-11	1.7E-11	2.7E-11	2E-07
I-125	CH_3I	15	1.4E-11	1.1E-11	1.4E-11	1.4E-07
I-125	Elem	Adults	1.5E-11	1.2E-11	1.5E-11	1.1E-07
I-125	Elem	0.25	2.4E-10	1E-10	5.0E-10	7.6E-07
I-125	Elem	1	1.7E-10	6.7E-11	2.9E-10	7.7E-07
I-125	Elem	5	8.0E-11	3.5E-11	1.2E-10	4.7E-07
I-125	Elem	10	4.3E-11	2.2E-11	3.9E-11	2.6E-07
I-125	Elem	15	1.9E-11	1.4E-11	2.1E-11	1.7E-07
I-125	F	Adults	6.1E-12	4.7E-12	5.7E-12	4.2E-08
I-125	F	0.25	1.1E-10	4.6E-11	2.2E-10	3.3E-07
I-125	F	1	8.1E-11	3.1E-11	1.3E-10	3.4E-07
I-125	F	5	3.3E-11	1.4E-11	4.7E-11	1.8E-07
I-125	F	10	1.8E-11	8.9E-12	1.6E-11	1.0E-07
I-125	F	15	7.3E-12	5.3E-12	7.7E-12	6.3E-08
I-131	CH_3I	Adults	6.8E-11	6.7E-11	3.7E-11	5.8E-08
I-131	CH_3I	0.25	5.0E-10	3.6E-10	1.3E-09	5.0E-07
I-131	CH_3I	1	3.7E-10	2.6E-10	7.3E-10	5.0E-07
I-131	CH_3I	5	2.2E-10	1.5E-10	2.8E-10	2.8E-07
I-131	CH_3I	10	1.4E-10	1.0E-10	9.1E-11	1.4E-07
I-131	CH_3I	15	8.3E-11	7.7E-11	5.0E-11	9.0E-08
I-131	Elem	Adults	9.1E-11	8.8E-11	6.1E-11	7.4E-08
I-131	Elem	0.25	6.6E-10	4.7E-10	1.9E-09	6.6E-07
I-131	Elem	1	4.9E-10	3.3E-10	1.0E-09	6.4E-07
I-131	Elem	5	2.9E-10	2.0E-10	4.1E-10	3.6E-07
I-131	Elem	10	1.9E-10	1.4E-10	1.5E-10	1.8E-07
I-131	Elem	15	1.1E-10	1.0E-10	8.1E-11	1.2E-07
I-131	F	Adults	3.9E-11	3.5E-11	2.4E-11	2.8E-08

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
I-131	F	0.25	3.4E-10	2.1E-10	8.3E-10	2.8E-07
I-131	F	1	2.5E-10	1.6E-10	4.7E-10	2.8E-07
I-131	F	5	1.3E-10	8.1E-11	1.7E-10	1.4E-07
I-131	F	10	8.3E-11	5.7E-11	6.2E-11	7.0E-08
I-131	F	15	4.6E-11	3.9E-11	3.0E-11	4.2E-08
I-133	CH_3I	Adults	3.2E-11	3.3E-11	3.0E-11	6.0E-08
I-133	CH_3I	0.25	3.0E-10	2.7E-10	3.4E-10	7.0E-07
I-133	CH_3I	1	2.0E-10	1.8E-10	2.0E-10	6.3E-07
I-133	CH_3I	5	1.1E-10	9.4E-11	1.0E-10	3.3E-07
I-133	CH_3I	10	6.4E-11	6.0E-11	5.8E-11	1.5E-07
I-133	CH_3I	15	3.9E-11	3.9E-11	3.6E-11	9.6E-08
I-133	Elem	Adults	4.5E-11	4.4E-11	5.3E-11	7.6E-08
I-133	Elem	0.25	4.1E-10	3.5E-10	6.0E-10	8.9E-07
I-133	Elem	1	2.7E-10	2.3E-10	3.6E-10	8.0E-07
I-133	Elem	5	1.5E-10	1.2E-10	1.8E-10	4.2E-07
I-133	Elem	10	8.9E-11	8.0E-11	1.1E-10	1.9E-07
I-133	Elem	15	5.5E-11	5.3E-11	6.4E-11	1.2E-07
I-133	F	Adults	2.5E-11	1.8E-11	2.1E-11	2.8E-08
I-133	F	0.25	2.5E-10	1.6E-10	2.9E-10	3.8E-07
I-133	F	1	1.7E-10	1.1E-10	1.8E-10	3.5E-07
I-133	F	5	8.4E-11	5.3E-11	8.0E-11	1.6E-07
I-133	F	10	5.1E-11	3.5E-11	4.6E-11	7.4E-08
I-133	F	15	2.9E-11	2.1E-11	2.4E-11	4.4E-08
Cs-134	F	Adults	1.2E-09	1.2E-09	1.4E-09	0
Cs-134	F	0.25	6.9E-09	6.4E-09	1.1E-08	0
Cs-134	F	1	4.5E-09	4.2E-09	7.6E-09	0
Cs-134	F	5	2.4E-09	2.4E-09	3.8E-09	0
Cs-134	F	10	1.8E-09	1.8E-09	2.4E-09	0
Cs-134	F	15	1.3E-09	1.4E-09	1.5E-09	0
Cs-136	F	Adults	7.8E-10	8.2E-10	9.6E-10	0
Cs-136	F	0.25	4.9E-09	4.4E-09	7.2E-09	0
Cs-136	F	1	3.3E-09	3.0E-09	5.0E-09	0
Cs-136	F	5	1.8E-09	1.7E-09	2.6E-09	0
Cs-136	F	10	1.3E-09	1.3E-09	1.6E-09	0
Cs-136	F	15	8.9E-10	8.9E-10	1.0E-09	0
Cs-137	F	Adults	7.6E-10	7.8E-10	9.6E-10	0
Cs-137	F	0.25	5.3E-09	5.1E-09	1.1E-08	0
Cs-137	F	1	3.3E-09	3.2E-09	7.3E-09	0
Cs-137	F	5	1.7E-09	1.7E-09	3.3E-09	0
Cs-137	F	10	1.2E-09	1.2E-09	2.0E-09	0
Cs-137	F	15	8.6E-10	8.6E-10	1.1E-09	0
Ra-226	M	Adults	1.2E-06	2.1E-09	0	0
Ra-226	M	0.25	1.0E-05	9.8E-08	0	0
Ra-226	M	1	7.0E-06	1.8E-08	0	0
Ra-226	M	5	3.5E-06	7.3E-09	0	0
Ra-226	M	10	2.1E-06	7.0E-09	0	0
Ra-226	M	15	1.4E-06	6.6E-09	0	0

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
Ra-228	M	Adults	7.7E-08	2.6E-10	0	0
Ra-228	M	0.25	6.7E-07	9.3E-09	0	0
Ra-228	M	1	4.9E-07	2.3E-09	0	0
Ra-228	M	5	2.5E-07	9.6E-10	0	0
Ra-228	M	10	1.4E-07	7.7E-10	0	0
Ra-228	M	15	9.5E-08	6.8E-10	0	0
Th-228	M	Adults	6.0E-06	3.9E-08	0	0
Th-228	M	0.25	5.3E-05	7.6E-07	0	0
Th-228	M	1	3.5E-05	4.1E-07	0	0
Th-228	M	5	1.9E-05	1.8E-07	0	0
Th-228	M	10	1.1E-05	1.0E-07	0	0
Th-228	M	15	7.0E-06	6.7E-08	0	0
Th-228	S	Adults	7.0E-06	6.9E-10	0	0
Th-228	S	0.25	6.0E-05	4.4E-08	0	0
Th-228	S	1	4.2E-05	7.2E-09	0	0
Th-228	S	5	2.2E-05	3.1E-09	0	0
Th-228	S	10	1.3E-05	1.8E-09	0	0
Th-228	S	15	8.4E-06	1.2E-09	0	0
Th-232	M	Adults	9.5E-07	1.2E-08	0	0
Th-232	M	0.25	8.4E-06	2.3E-07	0	0
Th-232	M	1	5.6E-06	1.4E-07	0	0
Th-232	M	5	3.0E-06	6.0E-08	0	0
Th-232	M	10	1.8E-06	3.1E-08	0	0
Th-232	M	15	1.1E-06	1.8E-08	0	0
Th-232	S	Adults	1.1E-06	1.9E-10	0	0
Th-232	S	0.25	9.8E-06	1.3E-08	0	0
Th-232	S	1	7.0E-06	2.3E-09	0	0
Th-232	S	5	3.5E-06	1.0E-09	0	0
Th-232	S	10	2.1E-06	5.3E-10	0	0
Th-232	S	15	1.3E-06	3.0E-10	0	0
U-234	F	Adults	3.5E-09	9.9E-09	0	0
U-234	F	0.25	3.1E-08	2.1E-07	0	0
U-234	F	1	2.4E-08	7.3E-08	0	0
U-234	F	5	1.1E-08	3.1E-08	0	0
U-234	F	10	6.3E-09	2.6E-08	0	0
U-234	F	15	3.4E-09	2.2E-08	0	0
U-234	M	Adults	1.1E-06	1.6E-09	0	0
U-234	M	0.25	9.8E-06	3.6E-08	0	0
U-234	M	1	7.0E-06	1.1E-08	0	0
U-234	M	5	3.5E-06	4.8E-09	0	0
U-234	M	10	2.1E-06	4.0E-09	0	0
U-234	M	15	1.3E-06	3.5E-09	0	0
U-234	S	Adults	1.3E-06	3.8E-11	0	0
U-234	S	0.25	1.2E-05	5.3E-09	0	0
U-234	S	1	8.1E-06	2.9E-10	0	0
U-234	S	5	4.2E-06	1.2E-10	0	0
U-234	S	10	2.5E-06	1.0E-10	0	0

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
U-234	S	15	1.6E-06	8.3E-11	0	0
U-235	F	Adults	3.3E-09	9.2E-09	0	0
U-235	F	0.25	2.9E-08	2.0E-07	0	0
U-235	F	1	2.2E-08	6.8E-08	0	0
U-235	F	5	1.1E-08	2.9E-08	0	0
U-235	F	10	6.0E-09	2.4E-08	0	0
U-235	F	15	3.1E-09	2.1E-08	0	0
U-235	M	Adults	1.1E-06	1.5E-09	0	0
U-235	M	0.25	9.1E-06	3.4E-08	0	0
U-235	M	1	6.3E-06	1.0E-08	0	0
U-235	M	5	3.3E-06	4.4E-09	0	0
U-235	M	10	1.9E-06	3.7E-09	0	0
U-235	M	15	1.2E-06	3.2E-09	0	0
U-235	S	Adults	1.2E-06	4.0E-11	0	0
U-235	S	0.25	1.1E-05	4.9E-09	0	0
U-235	S	1	7.7E-06	2.9E-10	0	0
U-235	S	5	3.9E-06	1.2E-10	0	0
U-235	S	10	2.3E-06	1.0E-10	0	0
U-235	S	15	1.5E-06	8.3E-11	0	0
U-238	F	Adults	3.1E-09	8.8E-09	0	0
U-238	F	0.25	2.8E-08	1.9E-07	0	0
U-238	F	1	2.1E-08	6.5E-08	0	0
U-238	F	5	1.0E-08	2.7E-08	0	0
U-238	F	10	5.6E-09	2.3E-08	0	0
U-238	F	15	3.0E-09	2.0E-08	0	0
U-238	M	Adults	9.8E-07	1.4E-09	0	0
U-238	M	0.25	8.8E-06	3.2E-08	0	0
U-238	M	1	6.0E-06	9.9E-09	0	0
U-238	M	5	3.1E-06	4.3E-09	0	0
U-238	M	10	1.8E-06	3.5E-09	0	0
U-238	M	15	1.2E-06	3.1E-09	0	0
U-238	S	Adults	1.2E-06	3.4E-11	0	0
U-238	S	0.25	1.1E-05	4.7E-09	0	0
U-238	S	1	7.4E-06	2.6E-10	0	0
U-238	S	5	3.9E-06	1.1E-10	0	0
U-238	S	10	2.2E-06	9.1E-11	0	0
U-238	S	15	1.4E-06	7.5E-11	0	0
Np-237	M	Adults	1.1E-06	1.0E-08	0	0
Np-237	M	0.25	9.8E-06	1.7E-07	0	0
Np-237	M	1	7.0E-06	1.0E-07	0	0
Np-237	M	5	3.5E-06	4.9E-08	0	0
Np-237	M	10	2.1E-06	2.6E-08	0	0
Np-237	M	15	1.3E-06	1.5E-08	0	0
Pu-238	M	Adults	1.3E-06	1.4E-08	0	0
Pu-238	M	0.25	1.2E-05	2.7E-07	0	0
Pu-238	M	1	8.1E-06	1.6E-07	0	0
Pu-238	M	5	4.2E-06	6.1E-08	0	0

Radionuclide	Sub-stance	Age (g), a	Organ or tissue			
			Lung	Red marrow	Colon	Thyroid
Pu-238	M	10	2.4E-06	3.2E-08	0	0
Pu-238	M	15	1.5E-06	1.9E-08	0	0
Pu-238	S	Adults	1.5E-06	1.8E-10	0	0
Pu-238	S	0.25	1.4E-05	3.5E-09	0	0
Pu-238	S	1	9.5E-06	2.0E-09	0	0
Pu-238	S	5	4.9E-06	7.7E-10	0	0
Pu-238	S	10	2.8E-06	4.0E-10	0	0
Pu-238	S	15	1.8E-06	2.4E-10	0	0
Pu-239, Pu-240	M	Adults	1.2E-06	1.3E-08	0	0
Pu-239, Pu-240	M	0.25	1.1E-05	2.6E-07	0	0
Pu-239, Pu-240	M	1	7.4E-06	1.5E-07	0	0
Pu-239, Pu-240	M	5	3.9E-06	5.7E-08	0	0
Pu-239, Pu-240	M	10	2.2E-06	3.0E-08	0	0
Pu-239, Pu-240	M	15	1.4E-06	1.7E-08	0	0
Pu-239, Pu-240	S	Adults	1.4E-06	1.7E-10	0	0
Pu-239, Pu-240	S	0.25	1.3E-05	3.3E-09	0	0
Pu-239, Pu-240	S	1	8.8E-06	1.9E-09	0	0
Pu-239, Pu-240	S	5	4.6E-06	7.3E-10	0	0
Pu-239, Pu-240	S	10	2.7E-06	3.8E-10	0	0
Pu-239, Pu-240	S	15	1.7E-06	2.3E-10	0	0
Am-241	M	Adults	1.3E-06	7.4E-09	0	0
Am-241	M	0.25	1.2E-05	3.0E-07	0	0
Am-241	M	1	8.1E-06	1.7E-07	0	0
Am-241	M	5	4.2E-06	5.5E-08	0	0
Am-241	M	10	2.4E-06	2.9E-08	0	0
Am-241	M	15	1.5E-06	1.7E-08	0	0
Cm-242	M	Adults	1.4E-06	7.7E-09	0	0
Cm-242	M	0.25	1.2E-05	3.1E-07	0	0
Cm-242	M	1	8.4E-06	1.8E-07	0	0
Cm-242	M	5	4.2E-06	5.7E-08	0	0
Cm-242	M	10	2.5E-06	3.0E-08	0	0
Cm-242	M	15	1.6E-06	1.7E-08	0	0
Cm-244	M	Adults	1.4E-06	7.8E-09	0	0
Cm-244	M	0.25	1.2E-05	3.1E-07	0	0
Cm-244	M	1	8.4E-06	1.8E-07	0	0
Cm-244	M	5	4.2E-06	5.8E-08	0	0
Cm-244	M	10	2.5E-06	3.0E-08	0	0
Cm-244	M	15	1.6E-06	1.8E-08	0	0
Cf-252	M	Adults	2.8E-06	3.3E-08	0	0
Cf-252	M	0.25	2.4E-05	5.7E-07	0	0
Cf-252	M	1	1.7E-05	3.4E-07	0	0
Cf-252	M	5	8.8E-06	1.5E-07	0	0
Cf-252	M	10	4.9E-06	7.8E-08	0	0
Cf-252	M	15	3.3E-06	4.6E-08	0	0

Remarks: * a) For details of RBE-weighted absorbed dose estimation see Introduction to Appendix XII;
b) F, M and S: respectively aerosol of Types F, M and S with AMAD 1 μm; Elem – elementary;
c) Lung – Alveolar region of Respiratory system (AI).

Part XII-C

Data for evaluation the intake of radionuclides in case of ingestion

XII-C1. Hydrogen

Dosimetric data

TABLE XII-C1-1. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF HYDROGEN [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
^{3}H (Tritium)	12.35 a	1.90E–3	β^- (0.0057 MeV mean) 100%

Biokinetic data

TABLE XII-C1-2. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR WATER (HTO)

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.2E-02	2.7E-02	8.4E-02	7.2E-02	5.6E-02	4.6E-02	3.4E-02
2	2.9E-02	2.9E-02	7.8E-02	6.9E-02	5.6E-02	4.7E-02	3.5E-02
3	2.8E-02	2.7E-02	6.2E-02	5.7E-02	4.8E-02	4.2E-02	3.3E-02
4	2.7E-02	2.5E-02	4.9E-02	4.7E-02	4.2E-02	3.7E-02	3.0E-02
5	2.4E-02	2.3E-02	4.0E-02	3.8E-02	3.6E-02	3.3E-02	2.7E-02
6	2.2E-02	2.2E-02	3.2E-02	3.2E-02	3.1E-02	2.9E-02	2.5E-02
7	2.1E-02	2.0E-02	2.5E-02	2.6E-02	2.7E-02	2.6E-02	2.3E-02
8	2.0E-02	1.9E-02	2.0E-02	2.2E-02	2.3E-02	2.3E-02	2.1E-02
9	1.8E-02	1.8E-02	1.6E-02	1.8E-02	2.0E-02	2.0E-02	1.9E-02
10	1.7E-02	1.7E-02	1.3E-02	1.5E-02	1.7E-02	1.8E-02	1.8E-02

TABLE XII-C1-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ORGANICALLY BOUND HYDROGEN (OBT)

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.3E-02	1.3E-02	5.0E-02	3.6E-02	2.8E-02	2.2E-02	1.7E-02
2	2.3E-02	2.3E-02	7.9E-02	5.7E-02	4.6E-02	3.6E-02	2.8E-02
3	2.2E-02	2.2E-02	7.0E-02	5.2E-02	4.2E-02	3.4E-02	2.7E-02
4	2.1E-02	2.1E-02	6.0E-02	4.5E-02	3.8E-02	3.2E-02	2.6E-02
5	2.0E-02	2.0E-02	5.2E-02	4.0E-02	3.5E-02	2.9E-02	2.4E-02
6	1.9E-02	1.9E-02	4.5E-02	3.5E-02	3.1E-02	2.7E-02	2.3E-02
7	1.8E-02	1.8E-02	3.9E-02	3.1E-02	2.9E-02	2.5E-02	2.1E-02
8	1.7E-02	1.7E-02	3.4E-02	2.8E-02	2.6E-02	2.3E-02	2.0E-02
9	1.7E-02	1.7E-02	3.0E-02	2.5E-02	2.4E-02	2.1E-02	1.9E-02
10	1.6E-02	1.6E-02	2.6E-02	2.3E-02	2.2E-02	2.0E-02	1.8E-02

XII-C2. Iron

Dosimetric data

TABLE XII-C2-1. IRON COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Iron	All unspecified compounds	A1

TABLE XII-C2-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF IRON [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Fe-59	44.5 d	1.56E–2	γ (1.1 MeV) 56%, γ (1.29 MeV) 44%

Biokinetic data

TABLE XII-C2-3. INGESTION INTAKE RETENTION IN WB (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF IRON

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.4E-01	7.4E-01	8.6E-01	7.6E-01	7.6E-01	7.6E-01	7.6E-01
2	3.9E-01	3.9E-01	7.1E-01	4.5E-01	4.5E-01	4.5E-01	4.5E-01
3	2.2E-01	2.2E-01	6.4E-01	3.0E-01	3.0E-01	3.0E-01	3.0E-01
4	1.5E-01	1.4E-01	6.1E-01	2.4E-01	2.4E-01	2.4E-01	2.4E-01
5	1.2E-01	1.2E-01	6.0E-01	2.1E-01	2.1E-01	2.1E-01	2.1E-01
6	1.1E-01	1.1E-01	6.0E-01	2.0E-01	2.0E-01	2.0E-01	2.1E-01
7	1.0E-01	1.0E-01	5.9E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
8	1.0E-01	1.0E-01	5.9E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
9	1.0E-01	1.0E-01	5.9E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
10	9.9E-02	1.0E-01	5.9E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01

TABLE XII-C2-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF IRON

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.9E-04	2.0E-04	3.9E-03	8.2E-04	3.6E-04	4.3E-04	3.3E-04
2	2.1E-05	2.1E-05	5.7E-04	8.6E-05	6.1E-05	5.5E-05	3.2E-05
3	1.3E-05	1.2E-05	2.4E-04	3.7E-05	3.5E-05	3.3E-05	1.9E-05
4	8.5E-06	8.5E-06	1.3E-04	2.1E-05	2.1E-05	2.1E-05	1.3E-05
5	6.3E-06	6.2E-06	8.7E-05	1.5E-05	1.3E-05	1.4E-05	9.2E-06
6	4.8E-06	4.8E-06	7.0E-05	1.2E-05	8.9E-06	1.0E-05	7.0E-06
7	3.9E-06	3.8E-06	6.2E-05	1.1E-05	6.5E-06	7.8E-06	5.6E-06
8	3.2E-06	3.2E-06	5.7E-05	1.0E-05	5.2E-06	6.3E-06	4.7E-06
9	2.8E-06	2.8E-06	5.4E-05	9.7E-06	4.5E-06	5.4E-06	4.1E-06
10	2.5E-06	2.5E-06	5.3E-05	9.4E-06	4.0E-06	4.9E-06	3.8E-06

XII-C3. Cobalt

Dosimetric data

TABLE XII-C3-1. COBALT COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Classes
Cobalt	Oxides, hydroxides and inorganic compounds	A2
	All unspecified compounds	A1

TABLE XII-C3-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF COBALT [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Co-57	271 d	2.56E-3	γ (0.122 MeV) 85.6%, γ (0.137 MeV) 10.6%
Co-58	70.8 d	9.79E–3	γ (0.511 MeV) 30%, γ (0.811 MeV) 99.4%
Co-60	5.27 a	3.60E–4	γ (1.17 MeV) 99.9%, γ (1.33 MeV) 100%

Biokinetic data

TABLE XII-C3-3. INGESTION INTAKE RETENTION IN WB (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF COBALT: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.1E-01	6.9E-01	7.0E-01	7.0E-01	7.0E-01	7.0E-01
2	3.5E-01	4.4E-01	3.8E-01	3.8E-01	3.8E-01	3.8E-01
3	1.6E-01	3.3E-01	2.3E-01	2.3E-01	2.3E-01	2.3E-01
4	8.7E-02	2.7E-01	1.6E-01	1.6E-01	1.6E-01	1.6E-01
5	5.6E-02	2.4E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01
6	4.3E-02	2.2E-01	1.2E-01	1.2E-01	1.2E-01	1.2E-01
7	3.7E-02	2.1E-01	1.1E-01	1.1E-01	1.1E-01	1.1E-01
8	3.4E-02	2.0E-01	9.9E-02	9.9E-02	9.9E-02	9.9E-02
9	3.2E-02	1.9E-01	9.4E-02	9.4E-02	9.4E-02	9.4E-02
10	3.0E-02	1.8E-01	8.9E-02	8.9E-02	8.9E-02	8.9E-02

TABLE XII-C3-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF COBALT: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-02	1.9E-01	8.9E-02	8.5E-02	8.5E-02	8.5E-02
2	1.4E-02	7.2E-02	3.9E-02	4.1E-02	4.1E-02	4.1E-02
3	5.5E-03	2.9E-02	1.5E-02	1.6E-02	1.6E-02	1.6E-02
4	3.1E-03	1.7E-02	8.8E-03	9.0E-03	9.0E-03	9.0E-03
5	2.3E-03	1.3E-02	6.7E-03	6.7E-03	6.7E-03	6.7E-03
6	1.9E-03	1.1E-02	5.7E-03	5.7E-03	5.7E-03	5.7E-03
7	1.7E-03	1.0E-02	5.0E-03	5.0E-03	5.0E-03	5.0E-03
8	1.5E-03	8.9E-03	4.5E-03	4.5E-03	4.5E-03	4.5E-03
9	1.4E-03	8.0E-03	4.0E-03	4.0E-03	4.0E-03	4.0E-03
10	1.2E-03	7.2E-03	3.6E-03	3.6E-03	3.6E-03	3.6E-03

TABLE XII-C3-5. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF COBALT: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.6E-01	1.4E-01	2.2E-01	2.2E-01	2.2E-01	2.2E-01
2	3.5E-01	1.6E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01
3	1.8E-01	8.5E-02	1.4E-01	1.4E-01	1.4E-01	1.4E-01
4	7.3E-02	3.8E-02	5.8E-02	5.8E-02	5.8E-02	5.8E-02
5	2.9E-02	1.6E-02	2.3E-02	2.3E-02	2.3E-02	2.3E-02
6	1.1E-02	7.6E-03	9.5E-03	9.5E-03	9.5E-03	9.5E-03
7	4.3E-03	4.0E-03	4.1E-03	4.1E-03	4.1E-03	4.1E-03
8	1.8E-03	2.5E-03	2.1E-03	2.1E-03	2.1E-03	2.1E-03
9	8.0E-04	1.9E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03
10	4.4E-04	1.5E-03	8.7E-04	8.7E-04	8.7E-04	8.7E-04

TABLE XII-C3-6. PREDICTED VALUES (MASS PER UNIT MASS INTAKE) FOR INGESTION OF COBALT BY WORKERS [12]

Time after intake [d]	Class A1			Class A2		
	WB retention	Daily urinary excretion	Daily faecal excretion	WB retention	Daily urinary excretion	Daily faecal excretion
1	7.1E-01	2.8E-02	2.6E-01	7.1E-01	1.4E-02	2.7E-01
2	3.5E-01	1.4E-02	3.5E-01	3.4E-01	7.3E-03	3.7E-01
3	1.6E-01	5.5E-03	1.8E-01	1.5E-01	2.8E-03	1.9E-01
4	8.7E-02	3.1E-03	7.3E-02	6.8E-02	1.5E-03	7.7E-02
5	5.6E-02	2.3E-03	2.9E-02	3.7E-02	1.1E-03	3.0E-02
6	4.3E-02	1.9E-03	1.1E-02	2.5E-02	9.6E-04	1.1E-02
7	3.7E-02	1.7E-03	4.3E-03	2.0E-02	8.4E-04	4.3E-03
8	3.4E-02	1.5E-03	1.8E-03	1.7E-02	7.5E-04	1.7E-03
9	3.2E-02	1.3E-03	8.0E-04	1.6E-02	6.7E-04	7.0E-04
10	3.0E-02	1.2E-03	4.4E-04	1.5E-02	6.1E-04	3.3E-04

XII-C4. Strontium

Dosimetric data

TABLE XII-C4-1. STRONTIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Classes
Strontium	Strontium titanate ($SrTiO_3$)	A2
	All unspecified compounds	A1

TABLE XII-C4-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF STRONTIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Sr-85	64.8 d	1.07E–2	γ (0.51 MeV) 98%
Sr-89	50.5 d	1.37E–2	β^- (0.58 MeV mean) 100%
Sr-90	29.1 a	6.53E–5	β^- (0.20 MeV mean) 100%, β^- of ^{90}Y (0.99 MeV mean) 100%

Biokinetic data

TABLE XII-C4-3. INGESTION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF STRONTIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.3E-01	8.4E-01	7.6E-01	7.5E-01	7.7E-01	7.9E-01
2	4.3E-01	6.7E-01	5.0E-01	4.9E-01	5.2E-01	5.5E-01
3	2.8E-01	5.8E-01	3.7E-01	3.6E-01	3.9E-01	4.3E-01
4	2.1E-01	5.4E-01	3.1E-01	2.9E-01	3.3E-01	3.8E-01
5	1.7E-01	5.2E-01	2.8E-01	2.6E-01	3.0E-01	3.5E-01
6	1.5E-01	5.0E-01	2.6E-01	2.4E-01	2.9E-01	3.4E-01
7	1.4E-01	4.9E-01	2.4E-01	2.3E-01	2.7E-01	3.3E-01
8	1.4E-01	4.9E-01	2.3E-01	2.2E-01	2.7E-01	3.2E-01
9	1.3E-01	4.8E-01	2.2E-01	2.1E-01	2.6E-01	3.2E-01
10	1.2E-01	4.7E-01	2.2E-01	2.0E-01	2.5E-01	3.1E-01

TABLE XII-C4-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF STRONTIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.7E-02	3.2E-02	5.1E-02	5.6E-02	3.9E-02	2.2E-02
2	2.2E-02	1.1E-02	1.9E-02	2.2E-02	1.5E-02	8.0E-03
3	1.4E-02	1.0E-02	1.5E-02	1.6E-02	1.2E-02	7.1E-03
4	1.1E-02	9.1E-03	1.2E-02	1.3E-02	1.0E-02	6.3E-03
5	8.3E-03	8.1E-03	1.0E-02	1.1E-02	9.0E-03	5.7E-03
6	6.8E-03	7.3E-03	8.9E-03	9.3E-03	7.8E-03	5.1E-03
7	5.7E-03	6.6E-03	7.7E-03	7.9E-03	6.8E-03	4.6E-03
8	4.8E-03	6.0E-03	6.7E-03	6.9E-03	6.0E-03	4.1E-03
9	4.2E-03	5.4E-03	5.9E-03	6.0E-03	5.4E-03	3.7E-03
10	3.7E-03	4.9E-03	5.2E-03	5.3E-03	4.8E-03	3.4E-03

TABLE XII-C4-5. PREDICTED VALUES (MASS PER UNIT MASS INTAKE) FOR INGESTION OF STRONTIUM BY WORKERS [12]

Time after intake [d]	Daily urinary excretion		Time after intake [d]	Daily urinary excretion	
	Class A1	Class A2		Class A1	Class A2
1	5.6E-02	1.8E-03	6	6.8E-03	2.3E-04
2	2.2E-02	7.6E-04	7	5.7E-03	1.9E-04
3	1.4E-02	4.9E-04	8	4.8E-03	1.6E-04
4	1.1E-02	3.6E-04	9	4.2E-03	1.4E-04
5	8.3E-03	2.8E-04	10	3.7E-03	1.2E-04

XII-C5. Ruthenium

Dosimetric data

TABLE XII-C5-1. RUTHENIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Ruthenium	All compounds	A1

TABLE XII-C5-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF RUTHENIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Ru-106	1.01 a	1.88E–3	γ (0.51 MeV) 21%, γ of ^{106}Rh (0.62 MeV) 10%, γ (1.1 MeV) 1%, β^- (1.51 MeV mean) 78.8%,

Biokinetic data

TABLE XII-C5-3. INGESTION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF RUTHENIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.2E-01	7.2E-01	7.3E-01	7.2E-01	7.2E-01	7.2E-01	7.2E-01
2	3.5E-01	3.5E-01	3.7E-01	3.5E-01	3.5E-01	3.5E-01	3.5E-01
3	1.6E-01	1.6E-01	1.9E-01	1.6E-01	1.6E-01	1.6E-01	1.6E-01
4	8.4E-02	8.4E-02	1.2E-01	8.4E-02	8.4E-02	8.4E-02	8.4E-02
5	5.3E-02	5.3E-02	8.8E-02	5.3E-02	5.3E-02	5.3E-02	5.3E-02
6	4.1E-02	4.1E-02	7.5E-02	4.1E-02	4.1E-02	4.1E-02	4.1E-02
7	3.6E-02	3.6E-02	6.9E-02	3.6E-02	3.6E-02	3.6E-02	3.6E-02
8	3.3E-02	3.3E-02	6.5E-02	3.3E-02	3.3E-02	3.3E-02	3.3E-02
9	3.1E-02	3.1E-02	6.2E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
10	3.0E-02	3.0E-02	6.0E-02	3.0E-02	3.0E-02	3.0E-02	3.0E-02

TABLE XII-C5-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF RUTHENIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	5.3E-03	5.3E-03	1.1E-02	5.5E-03	5.3E-03	5.3E-03	5.3E-03
2	2.4E-03	2.4E-03	4.4E-03	2.3E-03	2.4E-03	2.4E-03	2.4E-03
3	1.4E-03	1.4E-03	2.7E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03
4	1.2E-03	1.2E-03	2.4E-03	1.2E-03	1.2E-03	1.2E-03	1.2E-03
5	1.1E-03	1.1E-03	2.2E-03	1.1E-03	1.1E-03	1.1E-03	1.1E-03
6	1.0E-03	1.0E-03	2.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
7	9.4E-04	9.4E-04	1.9E-03	9.4E-04	9.4E-04	9.4E-04	9.4E-04
8	8.7E-04	8.7E-04	1.8E-03	8.7E-04	8.7E-04	8.7E-04	8.7E-04
9	8.1E-04	8.1E-04	1.6E-03	8.1E-04	8.1E-04	8.1E-04	8.1E-04
10	7.6E-04	7.6E-04	1.5E-03	7.6E-04	7.6E-04	7.6E-04	7.6E-04

XII-C6. Iodine

Dosimetric data

TABLE XII-C6-1. IODINE COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Iodine	All compounds	A1

TABLE XII-C6-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF IODINE [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
I-125	60.1 d	1.15E–2	X (0.027-0.032 MeV) 140%, γ (0.035 MeV) 6.7%
I-131	8.04 d	8.62E–2	β^- (0.19 MeV mean) 89%, γ (0.36 MeV) 81%
I-133	20.8 h	0.80	β^- (0.41 MeV mean) 97%; γ (0.53 MeV) 86%

Biokinetic data

TABLE XII-C6-3. INGESTION INTAKE RETENTION IN THYROID (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF IODINE

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.7E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01	2.7E-01
2	2.9E-01	2.9E-01	2.7E-01	2.8E-01	2.8E-01	2.9E-01	2.9E-01
3	2.9E-01	2.9E-01	2.6E-01	2.7E-01	2.8E-01	2.9E-01	2.9E-01
4	2.9E-01	2.9E-01	2.5E-01	2.6E-01	2.7E-01	2.9E-01	2.9E-01
5	2.9E-01	2.9E-01	2.3E-01	2.5E-01	2.6E-01	2.8E-01	2.8E-01
6	2.8E-01	2.8E-01	2.2E-01	2.4E-01	2.6E-01	2.8E-01	2.8E-01
7	2.8E-01	2.8E-01	2.1E-01	2.3E-01	2.5E-01	2.8E-01	2.8E-01
8	2.8E-01	2.8E-01	2.0E-01	2.2E-01	2.4E-01	2.7E-01	2.8E-01
9	2.8E-01	2.8E-01	1.9E-01	2.2E-01	2.4E-01	2.7E-01	2.7E-01
10	2.7E-01	2.8E-01	1.9E-01	2.1E-01	2.3E-01	2.7E-01	2.7E-01

TABLE XII-C6-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF IODINE

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	6.3E-01	6.3E-01	6.3E-01	6.3E-01	6.3E-01	6.3E-01	6.3E-01
2	6.0E-02	6.0E-02	5.3E-02	5.2E-02	6.1E-02	6.0E-02	6.0E-02
3	3.9E-03	3.9E-03	9.2E-03	7.0E-03	5.6E-03	4.1E-03	4.0E-03
4	4.4E-04	4.4E-04	7.6E-03	5.2E-03	2.8E-03	7.6E-04	6.4E-04
5	2.8E-04	2.8E-04	8.0E-03	5.7E-03	3.1E-03	7.0E-04	5.4E-04
6	3.3E-04	3.3E-04	8.1E-03	5.9E-03	3.5E-03	8.2E-04	6.4E-04
7	3.9E-04	3.9E-04	8.0E-03	6.1E-03	3.7E-03	9.4E-04	7.4E-04
8	4.5E-04	4.5E-04	7.8E-03	6.1E-03	3.8E-03	1.0E-03	8.2E-04
9	5.0E-04	5.0E-04	7.5E-03	6.0E-03	3.9E-03	1.1E-03	9.0E-04
10	5.4E-04	5.4E-04	7.2E-03	5.8E-03	4.0E-03	1.2E-03	9.7E-04

XII-C7. Caesium

Dosimetric data

TABLE XII-C7-1. CAESIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Caesium	All compounds	A1

TABLE XII-C7-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF CESIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Cs-134	2.06 a	9.22E–4	γ (0.60 MeV) 98%, γ (0.80 MeV) 85%
Cs-137	30.0 a	6.33E–5	γ of 137mBa (0.662 MeV) 85%

Biokinetic data

TABLE XII-C7-3. INGESTION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF CAESIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	9.8E-01	9.8E-01	9.8E-01	9.7E-01	9.8E-01	9.8E-01	9.8E-01
2	9.5E-01	9.5E-01	9.4E-01	9.3E-01	9.4E-01	9.4E-01	9.4E-01
3	9.3E-01	9.3E-01	9.0E-01	8.8E-01	8.9E-01	9.0E-01	9.1E-01
4	9.1E-01	9.1E-01	8.6E-01	8.3E-01	8.6E-01	8.7E-01	8.9E-01
5	8.9E-01	8.9E-01	8.3E-01	7.9E-01	8.2E-01	8.3E-01	8.7E-01
6	8.8E-01	8.8E-01	7.9E-01	7.5E-01	7.8E-01	8.1E-01	8.5E-01
7	8.7E-01	8.7E-01	7.6E-01	7.1E-01	7.5E-01	7.8E-01	8.4E-01
8	8.6E-01	8.6E-01	7.2E-01	6.7E-01	7.2E-01	7.5E-01	8.3E-01
9	8.5E-01	8.5E-01	6.9E-01	6.4E-01	6.9E-01	7.3E-01	8.2E-01
10	8.4E-01	8.5E-01	6.6E-01	6.1E-01	6.6E-01	7.1E-01	8.1E-01

TABLE XII-C7-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF CAESIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.6E-02	1.6E-02	2.0E-02	2.4E-02	2.0E-02	1.9E-02	1.9E-02
2	2.3E-02	2.3E-02	3.2E-02	3.9E-02	3.4E-02	3.2E-02	2.8E-02
3	1.8E-02	1.8E-02	3.1E-02	3.8E-02	3.3E-02	3.0E-02	2.2E-02
4	1.4E-02	1.4E-02	3.0E-02	3.6E-02	3.1E-02	2.7E-02	1.8E-02
5	1.1E-02	1.1E-02	2.9E-02	3.4E-02	2.9E-02	2.5E-02	1.4E-02
6	9.2E-03	9.2E-03	2.8E-02	3.2E-02	2.8E-02	2.3E-02	1.2E-02
7	7.8E-03	7.8E-03	2.6E-02	3.1E-02	2.6E-02	2.1E-02	9.8E-03
8	6.7E-03	6.7E-03	2.5E-02	2.9E-02	2.4E-02	1.9E-02	8.5E-03
9	6.0E-03	6.0E-03	2.4E-02	2.7E-02	2.3E-02	1.8E-02	7.5E-03
10	5.5E-03	5.5E-03	2.3E-02	2.6E-02	2.2E-02	1.6E-02	6.7E-03

XII-C8. Radium

Dosimetric data

TABLE XII-C8-1. RADIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Radium	All compounds	A1

TABLE XII-C8-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF RADIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Ra-226	1.60E3 a	1.19E–6	α (4.6 MeV) 6%, α (4.8 MeV) 94%, γ (0.19 MeV) 3% + γ of the progenies of ^{222}Rn
Ra-228	5.75 a	3.30E-4	γ of ^{228}Ac (0.34 MeV) 16%, γ (0.91 MeV) 29%, γ (0.96 MeV) 23% + γ of the progenies of ^{220}Rn

Biokinetic data

TABLE XII-C8-3. INGESTION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR RADIUM: ANY COMPOUNDS

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.3E-01	7.4E-01	8.4E-01	7.6E-01	7.5E-01	7.6E-01	7.7E-01
2	3.8E-01	4.0E-01	6.5E-01	4.4E-01	4.3E-01	4.6E-01	4.8E-01
3	1.9E-01	2.2E-01	5.4E-01	2.7E-01	2.6E-01	2.9E-01	3.3E-01
4	1.1E-01	1.4E-01	4.8E-01	1.9E-01	1.7E-01	2.2E-01	2.6E-01
5	6.9E-02	9.4E-02	4.5E-01	1.5E-01	1.3E-01	1.8E-01	2.3E-01
6	5.1E-02	7.3E-02	4.3E-01	1.2E-01	1.1E-01	1.6E-01	2.1E-01
7	4.1E-02	6.0E-02	4.1E-01	1.1E-01	9.7E-02	1.4E-01	2.0E-01
8	3.5E-02	5.3E-02	3.9E-01	1.0E-01	8.8E-02	1.3E-01	1.9E-01
9	3.2E-02	4.8E-02	3.8E-01	9.4E-02	8.1E-02	1.3E-01	1.9E-01
10	2.9E-02	4.4E-02	3.7E-01	8.8E-02	7.6E-02	1.2E-01	1.8E-01

TABLE XII-C8-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR RADIUM: ANY COMPOUNDS

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.9E-03	4.4E-03	2.6E-03	3.1E-03	3.4E-03	2.3E-03	1.3E-03
2	5.7E-04	8.4E-04	8.0E-04	7.4E-04	8.0E-04	6.5E-04	4.2E-04
3	3.7E-04	5.6E-04	6.6E-04	5.5E-04	5.7E-04	5.0E-04	3.4E-04
4	2.6E-04	3.9E-04	5.6E-04	4.2E-04	4.3E-04	4.0E-04	2.9E-04
5	1.8E-04	2.7E-04	4.7E-04	3.2E-04	3.2E-04	3.2E-04	2.4E-04
6	1.3E-04	1.9E-04	4.0E-04	2.5E-04	2.4E-04	2.5E-04	2.1E-04
7	9.1E-05	1.4E-04	3.4E-04	1.9E-04	1.8E-04	2.1E-04	1.8E-04
8	6.6E-05	9.8E-05	2.9E-04	1.5E-04	1.4E-04	1.7E-04	1.5E-04
9	4.8E-05	7.1E-05	2.5E-04	1.2E-04	1.1E-04	1.4E-04	1.3E-04
10	3.6E-05	5.3E-05	2.2E-04	9.5E-05	8.6E-05	1.1E-04	1.1E-04

XII-C9. Thorium

Dosimetric data

TABLE XII-C9-1. THORIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Classes
Thorium	Oxides and hydroxides	A2
	All unspecified compounds	A1

TABLE XII-C9-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF THORIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Th-228	1.91 a	9.94E–4	α (5.3 MeV) 27%, α (5.4 MeV) 73% + γ from the progenies of ^{220}Rn
Th-232	1.40E10 a	1.36E–13	α (3.95-4.01 MeV) 100%, γ of ^{228}Ac (0.34 MeV) 16%, γ (0.91 MeV) 29%, γ (0.96 MeV) 23% + same as ^{228}Th

Biokinetic data

TABLE XII-C9-3. INGESTION INTAKE RETENTION IN WHOLE BODY (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF INGESTION OF ANY COMPOUNDS OF THORIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Adult	0.25 a	1 a	5 a	10 a	15 a
1	7.2E-01	7.2E-01	7.2E-01	7.2E-01	7.2E-01	7.2E-01
2	3.3E-01	3.3E-01	3.3E-01	3.3E-01	3.3E-01	3.3E-01
3	1.3E-01	1.4E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01
4	5.1E-02	5.5E-02	5.1E-02	5.1E-02	5.1E-02	5.1E-02
5	1.9E-02	2.3E-02	1.9E-02	1.9E-02	1.9E-02	1.9E-02
6	7.4E-03	1.2E-02	7.4E-03	7.4E-03	7.4E-03	7.4E-03
7	3.0E-03	7.3E-03	3.0E-03	3.0E-03	3.0E-03	3.0E-03
8	1.4E-03	5.7E-03	1.4E-03	1.4E-03	1.4E-03	1.4E-03
9	8.1E-04	5.1E-03	8.2E-04	8.2E-04	8.3E-04	8.3E-04
10	5.9E-04	4.9E-03	6.0E-04	6.0E-04	6.0E-04	6.0E-04

TABLE XII-C9-4. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF THORIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Members of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.7E-05	1.2E-04	1.2E-05	1.1E-05	1.1E-05	1.1E-05
2	5.2E-06	3.1E-05	3.2E-06	3.5E-06	3.5E-06	3.5E-06
3	2.4E-06	1.5E-05	1.5E-06	1.6E-06	1.6E-06	1.6E-06
4	1.8E-06	1.2E-05	1.2E-06	1.2E-06	1.2E-06	1.2E-06
5	1.5E-06	1.0E-05	1.0E-06	1.0E-06	1.0E-06	1.0E-06
6	1.3E-06	8.4E-06	8.4E-07	8.4E-07	8.4E-07	8.4E-07
7	1.1E-06	7.2E-06	7.2E-07	7.2E-07	7.2E-07	7.2E-07
8	9.4E-07	6.3E-06	6.3E-07	6.3E-07	6.3E-07	6.3E-07
9	8.3E-07	5.6E-06	5.5E-07	5.5E-07	5.5E-07	5.5E-07
10	7.4E-07	5.0E-06	5.0E-07	5.0E-07	4.9E-07	4.9E-07

TABLE XII-C9-5. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF THORIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Members of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01
2	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01
3	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
4	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02
5	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
6	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
7	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03
8	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03
9	6.0E-04	5.9E-04	6.0E-04	6.0E-04	6.0E-04	6.0E-04
10	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04

TABLE XII-C9-6. PREDICTED VALUES (MASS PER UNIT MASS INTAKE) FOR INGESTION OF THORIUM BY WORKERS [12]

Time after intake [d]	Class A1			Class A2		
	Whole body retention	Daily urinary excretion	Daily faecal excretion	Whole body retention	Daily urinary excretion	Daily faecal excretion
1	7.2E-01	1.7E-05	2.8E-01	7.2E-01	6.7E-06	2.8E-01
2	3.3E-01	5.2E-06	3.9E-01	3.3E-01	2.1E-06	3.9E-01
3	1.3E-01	2.4E-06	2.0E-01	1.3E-01	9.4E-07	2.0E-01
4	5.1E-02	1.8E-06	8.1E-02	5.0E-02	7.3E-07	8.1E-02
5	1.9E-02	1.5E-06	3.1E-02	1.9E-02	6.0E-07	3.1E-02
6	7.4E-03	1.3E-06	1.2E-02	7.1E-03	5.0E-07	1.2E-02
7	3.0E-03	1.1E-06	4.4E-03	2.7E-03	4.3E-07	4.4E-03
8	1.4E-03	9.4E-07	1.6E-03	1.1E-03	3.8E-07	1.6E-03
9	8.1E-04	8.3E-07	6.0E-04	5.3E-04	3.3E-07	6.0E-04
10	5.9E-04	7.4E-07	2.2E-04	3.1E-04	3.0E-07	2.2E-04

XII-C10. Uranium

Dosimetric data

TABLE XII-C10-1. URANIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Classes
Uranium	Most tetravalent compounds, e.g. UO_2, U_3O_8, UF_4	A2
	All unspecified compounds	A1

TABLE XII-C10-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF URANIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
U-234	2.44E5 a	7.78E–9	α (4.72 MeV) 27%, α (4.77 MeV) 72%
U-235	7.04E8 a	2.70E–12	α (4.37 MeV) 18%, α (4.40 MeV) 56%, γ (0.144 MeV) 11%, (0.186 MeV) 54%
U-238	4.47E9 a	4.25E–13	α (4.15 MeV) 23%, α (4.20 MeV) 77%

Biokinetic data

TABLE XII-C10-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF URANIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Members of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
1	1.3E-02	1.7E-02	1.1E-02	1.1E-02	9.9E-03	8.3E-03
2	6.9E-04	1.0E-03	5.9E-04	6.7E-04	6.4E-04	5.9E-04
3	3.7E-04	7.4E-04	3.8E-04	3.8E-04	3.9E-04	3.7E-04
4	3.3E-04	6.7E-04	3.5E-04	3.5E-04	3.5E-04	3.4E-04
5	3.0E-04	6.2E-04	3.2E-04	3.1E-04	3.2E-04	3.1E-04
6	2.7E-04	5.7E-04	2.9E-04	2.9E-04	2.9E-04	2.9E-04
7	2.5E-04	5.2E-04	2.6E-04	2.6E-04	2.7E-04	2.6E-04
8	2.3E-04	4.8E-04	2.4E-04	2.4E-04	2.5E-04	2.4E-04
9	2.1E-04	4.4E-04	2.2E-04	2.2E-04	2.3E-04	2.2E-04
10	1.9E-04	4.1E-04	2.0E-04	2.0E-04	2.1E-04	2.1E-04

TABLE XII-C10-4. PREDICTED VALUES (MASS PER UNIT MASS INTAKE) FOR INGESTION OF URANIUM BY WORKERS [12]

Time after intake [d]	Daily urinary excretion		Time after intake [d]	Daily urinary excretion	
	Class A1	Class A2		Class A1	Class A2
1	1.3E-02	1.3E-03	6	2.7E-04	2.7E-05
2	6.9E-04	7.0E-05	7	2.5E-04	2.5E-05
3	3.7E-04	3.7E-05	8	2.3E-04	2.3E-05
4	3.3E-04	3.3E-05	9	2.1E-04	2.1E-05
5	3.0E-04	3.0E-05	10	1.9E-04	1.9E-05

XII-C11. Neptunium

Dosimetric data

TABLE XII-C11-1. NEPTUNIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Neptunium	All compounds	A1

TABLE XII-C11-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF NEPTUNIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Np-237	2.14E6 a	8.87E–10	α (4.79 MeV) 80%, X (0.013-0.017 MeV) 50%, γ (0.086 MeV) 12.6%

Biokinetic data

TABLE XII-C11-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF NEPTUNIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	9.8E-05	9.8E-05	4.5E-04	4.4E-05	6.7E-05	6.7E-05	6.7E-05
2	3.1E-05	3.1E-05	1.2E-04	1.3E-05	2.1E-05	2.1E-05	2.1E-05
3	1.2E-05	1.2E-05	5.4E-05	5.4E-06	8.5E-06	8.5E-06	8.5E-06
4	7.6E-06	7.6E-06	3.4E-05	3.4E-06	5.3E-06	5.3E-06	5.3E-06
5	5.0E-06	5.0E-06	2.3E-05	2.3E-06	3.5E-06	3.5E-06	3.5E-06
6	3.3E-06	3.3E-06	1.6E-05	1.6E-06	2.4E-06	2.4E-06	2.4E-06
7	2.3E-06	2.3E-06	1.1E-05	1.1E-06	1.7E-06	1.7E-06	1.6E-06
8	1.6E-06	1.6E-06	8.4E-06	8.3E-07	1.2E-06	1.2E-06	1.2E-06
9	1.1E-06	1.1E-06	6.5E-06	6.4E-07	8.6E-07	8.6E-07	8.6E-07
10	8.4E-07	8.4E-07	5.2E-06	5.1E-07	6.6E-07	6.6E-07	6.5E-07

TABLE XII-C11-4. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF NEPTUNIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01
2	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01
3	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
4	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02
5	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
6	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
7	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03
8	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03
9	6.0E-04	6.0E-04	5.9E-04	6.0E-04	6.0E-04	6.0E-04	6.0E-04
10	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04

XII-C12. Plutonium

Dosimetric data

TABLE XII-C12-1. PLUTONIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Classes
Plutonium	All unspecified compounds	A1
	Nitrates	A2
	Insoluble oxides	A3

TABLE XII-C12-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF PLUTONIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Pu-238	87.7 a	2.17E–5	α (5.46 MeV) 28%, (5.50 MeV) 72%
Pu-239	2.41E4 a	7.88E–8	α (5.11 MeV) 11%, (5.14 MeV) 15%, (5.16 MeV) 74%
Pu-240	6.54E3 a	2.90E–7	α (5.12 MeV) 27%, (5.17 MeV) 73%

Biokinetic data

TABLE XII-C12-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF PLUTONIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Members of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.4E-06	3.6E-05	3.6E-06	3.4E-06	3.4E-06	3.4E-06
2	2.6E-06	2.5E-05	2.5E-06	2.6E-06	2.6E-06	2.6E-06
3	1.4E-06	1.4E-05	1.4E-06	1.4E-06	1.4E-06	1.4E-06
4	9.3E-07	9.1E-06	9.1E-07	9.3E-07	9.3E-07	9.3E-07
5	6.5E-07	6.3E-06	6.4E-07	6.5E-07	6.5E-07	6.5E-07
6	4.7E-07	4.7E-06	4.7E-07	4.7E-07	4.7E-07	4.7E-07
7	3.6E-07	3.5E-06	3.5E-07	3.6E-07	3.6E-07	3.6E-07
8	2.8E-07	2.7E-06	2.7E-07	2.8E-07	2.8E-07	2.8E-07
9	2.2E-07	2.2E-06	2.2E-07	2.2E-07	2.2E-07	2.2E-07
10	1.8E-07	1.8E-06	1.8E-07	1.8E-07	1.8E-07	1.8E-07

TABLE XII-C12-4. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF PLUTONIUM: MEMBERS OF THE PUBLIC [59]

Time after intake [d]	Members of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01
2	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01
3	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
4	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02
5	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
6	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
7	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03
8	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03
9	6.0E-04	6.0E-04	6.0E-04	6.0E-04	6.0E-04	6.0E-04
10	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04

TABLE XII-C12-5. PREDICTED VALUES (MASS PER UNIT MASS INTAKE) FOR INGESTION OF PLUTONIUM BY WORKERS [12]

Time after intake [d]	Class A1		Class A2		Class A3	
	Daily urinary excretion	Daily faecal excretion	Daily urinary excretion	Daily faecal excretion	Daily urinary excretion	Daily faecal excretion
1	3.4E-06	2.8E-01	6.7E-07	2.8E-01	6.7E-08	2.8E-01
2	2.6E-06	3.9E-01	5.2E-07	3.9E-01	5.2E-08	3.9E-01
3	1.4E-06	2.0E-01	2.9E-07	2.0E-01	2.9E-08	2.0E-01
4	9.3E-07	8.1E-02	1.9E-07	8.1E-02	1.9E-08	8.1E-02
5	6.5E-07	3.1E-02	1.3E-07	3.1E-02	1.3E-08	3.1E-02
6	4.7E-07	1.2E-02	9.4E-08	1.2E-02	9.4E-09	1.2E-02
7	3.6E-07	4.4E-03	7.1E-08	4.4E-03	7.1E-09	4.4E-03
8	2.8E-07	1.6E-03	5.5E-08	1.6E-03	5.5E-09	1.6E-03
9	2.2E-07	6.0E-04	4.4E-08	6.0E-04	4.4E-09	6.0E-04
10	1.8E-07	2.2E-04	3.6E-08	2.2E-04	3.6E-09	2.2E-04

XII-C13. Americium

Dosimetric data

TABLE XII-C13-1. AMERICIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Americium	All compounds	A1

TABLE XII-C13-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF AMERICIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Am-241	4.32E2 a	4.40E–6	α (5.39 MeV) 1%, α (5.44 MeV) 13%, (5.49 MeV) 85%, γ (0.0595 MeV) 36%

Biokinetic data

TABLE XII-C13-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF AMERICIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.0E-05	3.0E-05	3.0E-04	3.0E-05	3.0E-05	3.0E-05	3.0E-05
2	4.6E-06	4.6E-06	4.3E-05	4.3E-06	4.6E-06	4.6E-06	4.6E-06
3	2.2E-06	2.2E-06	2.1E-05	2.1E-06	2.2E-06	2.2E-06	2.2E-06
4	1.3E-06	1.3E-06	1.3E-05	1.3E-06	1.3E-06	1.3E-06	1.3E-06
5	9.5E-07	9.5E-07	9.1E-06	9.0E-07	9.3E-07	9.3E-07	9.3E-07
6	7.6E-07	7.6E-07	7.4E-06	7.4E-07	7.5E-07	7.5E-07	7.5E-07
7	6.6E-07	6.6E-07	6.4E-06	6.3E-07	6.5E-07	6.4E-07	6.4E-07
8	5.9E-07	5.9E-07	5.7E-06	5.6E-07	5.8E-07	5.8E-07	5.7E-07
9	5.4E-07	5.4E-07	5.2E-06	5.1E-07	5.2E-07	5.2E-07	5.2E-07
10	4.9E-07	4.9E-07	4.7E-06	4.6E-07	4.8E-07	4.8E-07	4.8E-07

TABLE XII-C13-4. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF AMERICIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01
2	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01
3	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
4	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02
5	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
6	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
7	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03
8	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03
9	6.0E-04	6.0E-04	5.9E-04	6.0E-04	6.0E-04	6.0E-04	6.0E-04
10	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04

XII-C14. Curium

Dosimetric data

TABLE XII-C14-1. CURIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Curium	All compounds	A1

TABLE XII-C14-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF CURIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Cm-242	163 d	4.25E–3	α (6.07 MeV) 26%, α (6.11 MeV) 74%
Cm-244	18.1 a	1.05E–4	α (5.76 MeV) 24%, α (5.81 MeV) 76%

Biokinetic data

TABLE XII-C14-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF CURIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	3.0E-05	3.0E-05	3.0E-04	3.0E-05	6.7E-05	3.0E-05	3.0E-05
2	4.6E-06	4.6E-06	4.3E-05	4.3E-06	2.1E-05	4.6E-06	4.6E-06
3	2.2E-06	2.2E-06	2.1E-05	2.1E-06	8.5E-06	2.2E-06	2.2E-06
4	1.3E-06	1.3E-06	1.3E-05	1.3E-06	5.3E-06	1.3E-06	1.3E-06
5	9.5E-07	9.4E-07	9.2E-06	9.0E-07	3.5E-06	9.3E-07	9.3E-07
6	7.6E-07	7.6E-07	7.4E-06	7.3E-07	2.4E-06	7.5E-07	7.5E-07
7	6.6E-07	6.6E-07	6.4E-06	6.3E-07	1.7E-06	6.4E-07	6.4E-07
8	5.9E-07	5.9E-07	5.7E-06	5.6E-07	1.2E-06	5.8E-07	5.7E-07
9	5.4E-07	5.4E-07	5.1E-06	5.1E-07	8.6E-07	5.2E-07	5.2E-07
10	4.9E-07	4.9E-07	4.7E-06	4.6E-07	6.6E-07	4.8E-07	4.8E-07

TABLE XII-C14-4. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF CURIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01
2	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01
3	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
4	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02
5	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
6	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
7	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03
8	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03
9	6.0E-04	6.0E-04	5.9E-04	6.0E-04	6.0E-04	6.0E-04	6.0E-04
10	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04

XII-C15. Californium

Dosimetric data

TABLE XII-C15-1. CALIFORNIUM COMPOUNDS AND INGESTION CLASSES FOR INGESTION IN OCCUPATIONAL CONDITIONS [39]

Element	Compounds	Ingestion Class
Californium	All compounds	A1

TABLE XII-C15-2. PHYSICAL CHARACTERISTICS OF RADIONUCLIDES OF CALIFORNIUM [55]

Radionuclide	Half-life ($T_{1/2}$)	λ_R [d^{-1}]	Major radiation and yield
Cf-252	2.64 a	7.19E-4	fission n^0 (2.16 MeV mean) 12%, fission γ (0.88 MeV mean) 27%, fission γ (0.96 MeV mean) 25%, α (6.08 MeV) 15%, α (6.12 MeV) 82%

Biokinetic data

TABLE XII-C15-3. INGESTION INTAKE DAILY URINARY EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF CALIFORNIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.1E-05	2.1E-05	2.1E-04	2.1E-05	2.1E-05	2.1E-05	2.1E-05
2	3.8E-06	3.8E-06	3.2E-05	3.3E-06	3.8E-06	3.8E-06	3.8E-06
3	2.6E-07	2.6E-07	2.2E-06	2.2E-07	2.6E-07	2.6E-07	2.6E-07
4	2.8E-08	2.8E-08	2.5E-07	2.5E-08	2.8E-08	2.8E-08	2.8E-08
5	1.3E-08	1.3E-08	1.3E-07	1.3E-08	1.3E-08	1.3E-08	1.3E-08
6	1.2E-08	1.2E-08	1.2E-07	1.2E-08	1.2E-08	1.2E-08	1.2E-08
7	1.2E-08	1.2E-08	1.2E-07	1.2E-08	1.2E-08	1.2E-08	1.2E-08
8	1.2E-08	1.2E-08	1.2E-07	1.2E-08	1.2E-08	1.2E-08	1.2E-08
9	1.2E-08	1.2E-08	1.2E-07	1.2E-08	1.2E-08	1.2E-08	1.2E-08
10	1.2E-08	1.2E-08	1.2E-07	1.2E-08	1.2E-08	1.2E-08	1.2E-08

TABLE XII-C15-4. INGESTION INTAKE DAILY FAECAL EXCRETION (MASS PER UNIT MASS INTAKE) FOR ANY COMPOUNDS OF CALIFORNIUM

Time after intake [d]	Workers [12]	Members of the public [59]					
		Adult	0.25 a	1 a	5 a	10 a	15 a
1	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01	2.8E-01
2	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01	3.9E-01
3	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01	2.0E-01
4	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02	8.1E-02
5	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02	3.1E-02
6	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02	1.2E-02
7	4.4E-03	4.4E-03	4.3E-03	4.4E-03	4.4E-03	4.4E-03	4.4E-03
8	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03	1.6E-03
9	5.9E-04	5.9E-04	5.9E-04	5.9E-04	5.9E-04	5.9E-04	5.9E-04
10	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04	2.2E-04

Part XII-D
Data for evaluation the doses of internal exposure in case of ingestion intake of radionuclides

XII-D1. Data for evaluation the committed effective doses of internal exposure in case of ingestion intake of radionuclides

TABLE XII-D1-1. INGESTION: COMMITTED EFFECTIVE DOSE PER UNIT INTAKE $e_W^{Ing}(\tau)$ FOR WORKERS [Sv×Bq^{-1}] [39].

Radionuclide	Ingestion Class	e_W^{Ing}	Radionuclide	Ingestion Class	e_W^{Ing}
H-3	OBT	4.2E-11	Ra-228	A1	6.7E-07
H-3	HTO	1.8E-11	Th-228	A1	7.0E-08
Fe-59	A1	1.8E-09	Th-228	A2	3.5E-08
Co-57	A1	2.1E-10	Th-232	A1	2.2E-07
Co-57	A2	1.9E-10	Th-232	A2	9.2E-08
Co-58	A1	7.4E-10	U-234	A1	4.9E-08
Co-58	A2	7.0E-10	U-234	A2	8.3E-09
Co-60	A1	3.4E-09	U-235	A1	4.6E-08
Co-60	A2	2.5E-09	U-235	A2	8.3E-09
Sr-85	A1	5.6E-10	U-238	A1	4.4E-08
Sr-85	A2	3.3E-10	U-238	A2	7.6E-09
Sr-89	A1	2.6E-09	Np-237	A1	1.1E-07
Sr-89	A2	2.3E-09	Pu-238	A1	2.3E-07
Sr-90	A1	2.8E-08	Pu-238	A2	8.8E-09
Sr-90	A2	2.7E-09	Pu-238	A3	4.9E-08
Ru-106	A1	7.0E-09	Pu-239, Pu-240	A1	2.5E-07
I-125	A1	1.5E-08	Pu-239, Pu-240	A2	9.0E-09
I-131	A1	2.2E-08	Pu-239, Pu-240	A3	5.3E-08
I-133	A1	4.3E-09	Am-241	A1	2.0E-07
Cs-134	A1	1.9E-08	Cm-242	A1	1.2E-08
Cs-137	A1	1.3E-08	Cm-244	A1	1.2E-07
Ra-226	A1	2.8E-07	Cf-252	A1	9.0E-08

TABLE XII-D1-2. INGESTION: COMMITTED EFFECTIVE DOSE PER UNIT INTAKE $e_P^{Ing}(g,\tau)$ FOR MEMBERS OF THE PUBLIC [Sv×Bq^{-1}] [39]

Radionuclide	Age *(g)* of the member of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
H-3	1.8E-11	6.4E-11	4.8E-11	3.1E-11	2.3E-11	1.8E-11
OBT	4.2E-11	1.2E-10	1.2E-10	7.3E-11	5.7E-11	4.2E-11
Fe-59	1.8E-09	3.9E-08	1.3E-08	7.5E-09	4.7E-09	3.1E-09
Co-57	2.1E-10	2.9E-09	1.6E-09	8.9E-10	5.8E-10	3.7E-10
Co-58	7.4E-10	7.3E-09	4.4E-09	2.6E-09	1.7E-09	1.1E-09
Co-60	3.4E-09	5.4E-08	2.7E-08	1.7E-08	1.1E-08	7.9E-09
Sr-85	5.6E-10	7.7E-09	3.1E-09	1.7E-09	1.5E-09	1.3E-09
Sr-89	2.6E-09	3.6E-08	1.8E-08	8.9E-09	5.8E-09	4.0E-09
Sr-90	2.8E-08	2.3E-07	7.3E-08	4.7E-08	6.0E-08	8.0E-08
Ru-106	7.0E-09	8.4E-08	4.9E-08	2.5E-08	1.5E-08	8.6E-09
I-125	1.5E-08	5.2E-08	5.7E-08	4.1E-08	3.1E-08	2.2E-08

Radionuclide	Age *(g)* of the member of the public					
	Adult	0.25 a	1 a	5 a	10 a	15 a
I-131	2.2E-08	1.8E-07	1.8E-07	1.0E-07	5.2E-08	3.4E-08
I-133	4.3E-09	4.9E-08	4.4E-08	2.3E-08	1.0E-08	6.8E-09
Cs-134	1.9E-08	2.6E-08	1.6E-08	1.3E-08	1.4E-08	1.9E-08
Cs-137	1.3E-08	2.1E-08	1.2E-08	9.6E-09	1.0E-08	1.3E-08
Ra-226	2.8E-07	4.7E-06	9.6E-07	6.2E-07	8.0E-07	1.5E-06
Ra-228	6.9E-07	3.0E-05	5.7E-06	3.4E-06	3.9E-06	5.3E-06
Th-228	7.2E-08	3.7E-06	3.7E-07	2.2E-07	1.4E-07	9.4E-08
Th-232	2.3E-07	4.6E-06	4.5E-07	3.5E-07	2.9E-07	2.5E-07
U-234	4.9E-08	3.7E-07	1.3E-07	8.8E-08	7.4E-08	7.4E-08
U-235	4.7E-08	3.5E-07	1.3E-07	8.5E-08	7.1E-08	7.0E-08
U-238	4.5E-08	3.4E-07	1.2E-07	8.0E-08	6.8E-08	6.7E-08
Np-237	1.1E-07	2.0E-06	2.1E-07	1.4E-07	1.1E-07	1.1E-07
Pu-238	2.3E-07	4.0E-06	4.0E-07	3.1E-07	2.4E-07	2.2E-07
Pu-239, Pu-240	2.5E-07	4.2E-06	4.2E-07	3.3E-07	2.7E-07	2.4E-07
Am-241	2.0E-07	3.7E-06	3.7E-07	2.7E-07	2.2E-07	2.0E-07
Cm-242	1.2E-08	5.9E-07	7.6E-08	3.9E-08	2.4E-08	1.5E-08
Cm-244	1.2E-07	2.9E-06	2.9E-07	1.9E-07	1.4E-07	1.2E-07
Cf-252	9.0E-08	5.0E-06	5.1E-07	3.2E-07	1.9E-07	1.0E-07

XII-D2. Data for evaluation the RBE-weighted absorbed doses to organs and tissues of workers from ingestion intake of radionuclides

TABLE XII-D2-1. INGESTION: COMMITTED RBE-WEIGHTED ABSORBED DOSE TO THE OFFSPRING $Ad^{Ing}_{W,offspring}(\Delta)$ PER UNIT INTAKE OF FEMALE WORKER [Gy-Eq×Bq^{-1}]*

Radionuclide	Ingestion Class	$Ad^{Ing}_{W,offspring}$	Radionuclide	Ingestion Class	$Ad^{Ing}_{W,offspring}$
H-3	OBT	7.6E-11	Th-228	A1	1.3E-08
H-3	HTO	3.6E-11	Th-228	A2	5.5E-09
Fe-59	A1	2.7E-09	Th-232	A1	1.2E-08
Co-57	A1	1.5E-10	Th-232	A2	5.0E-09
Co-57	A2	1.2E-10	U-234	A1	9.0E-09
Co-58	A1	7.0E-10	U-234	A2	9.0E-10
Co-58	A2	6.5E-10	U-235	A1	8.0E-09
Co-60	A1	2.3E-09	U-235	A2	8.5E-10
Co-60	A2	1.9E-09	U-238	A1	7.5E-09
Sr-89	A1	1.9E-08	U-238	A1	7.5E-10
Sr-89	A2	6.2E-10	Np-237	A1	4.5E-09
Sr-90	A1	7.0E-08	Pu-238	A1	1.2E-08
Sr-90	A2	2.3E-09	Pu-238	A2	2.4E-09
Ru-106	A1	7.4E-10	Pu-238	A3	2.4E-10
I-125	A1	1.9E-08	Pu-239, Pu-240	A1	1.2E-08
I-131	A1	6.0E-08	Pu-239, Pu-240	A2	2.5E-09
I-133	A1	1.3E-08	Pu-239, Pu-240	A3	2.5E-10
Cs-134	A1	1.1E-08	Am-241	A1	1.5E-09
Cs-137	A1	7.2E-09	Cm-242	A1	2.6E-10
Ra-226	A1	2.5E-07	Cm-244	A1	1.2E-09
Ra-228	A1	4.2E-07			

Remarks: * For details of RBE-weighted absorbed dose estimation see Introduction to Appendix XII.

TABLE XII-D2-2. COMMITTED RBE-WEIGHTED ABSORBED DOSE PER UNIT INTAKE $Ad_{W,T}^{Ing}(\Delta)$ DELIVERED IN ORGAN OR TISSUE OF REFERENCE WORKER OVER 30 DAYS AFTER ACUTE INGESTION INTAKE [Gy-Eq×Bq^{-1}]

Radionuclide	Compound	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
H-3	OBT	2.1E-11	2.1E-11	2.2E-11	0
H-3	HTO	1.5E-11	1.5E-11	1.5E-11	0
Fe-59	A1	2.7E-10	7.7E-10	5.4E-09	0
Co-57	A1	1.4E-11	3.5E-11	8.9E-10	0
Co-57	A2	7.7E-12	3.1E-11	9.3E-10	0
Co-58	A1	7.6E-11	2.3E-10	2.7E-09	0
Co-58	A2	4.8E-11	2.1E-10	2.8E-09	0
Co-60	A1	2.1E-10	5.7E-10	6.9E-09	0
Co-60	A2	1.3E-10	5.1E-10	7.2E-09	0
Sr-85	A1	1.2E-10	3.7E-10	1.1E-09	0
Sr-85	A2	1.3E-11	1.1E-10	1.3E-09	0
Sr-89	A1	1.7E-10	2.0E-09	1.4E-08	0
Sr-89	A2	5.8E-12	6.8E-11	1.8E-08	0
Sr-90	A1	3.1E-10	4.0E-09	1.2E-08	0
Sr-90	A2	1.0E-11	1.3E-10	1.5E-08	0
Ru-106	A1	2.5E-10	2.8E-10	4.4E-08	0
I-125	A1	1.6E-11	1.3E-11	2.4E-11	1.2E-07
I-131	A1	9.7E-11	9.5E-11	1.2E-10	8.0E-08
I-133	A1	4.5E-11	4.7E-11	1.1E-10	8.2E-08
Cs-134	A1	3.4E-09	3.6E-09	4.3E-09	0
Cs-136	A1	2.3E-09	2.4E-09	2.9E-09	0
Cs-137	A1	2.2E-09	2.3E-09	2.9E-09	0
Ra-226	A1	9.8E-10	7.4E-09	0	0
Ra-228	A1	9.1E-11	6.0E-10	0	0
Th-228	A1	2.1E-10	1.2E-09	0	0
Th-228	A2	1.7E-10	8.8E-10	0	0
Th-232	A1	1.8E-11	1.8E-10	0	0
Th-232	A2	7.4E-12	7.4E-11	0	0
U-234	A1	2.4E-10	8.1E-10	0	0
U-234	A2	2.4E-11	8.1E-11	0	0
U-235	A1	2.3E-10	7.6E-10	0	0
U-235	A2	2.3E-11	7.9E-11	0	0
U-238	A1	2.1E-10	7.2E-10	0	0
U-238	A2	2.2E-11	7.2E-11	0	0
Np-237	A1	1.5E-11	1.6E-10	0	0
Pu-238	A1	2.6E-11	2.1E-10	0	0
Pu-238	A2	5.3E-13	4.2E-12	0	0
Pu-238	A3	5.3E-12	4.2E-11	0	0
Pu-239, Pu-240	A2	2.5E-11	2.0E-10	0	0
Pu-239, Pu-240	A1	4.9E-13	4.0E-12	0	0
Pu-239, Pu-240	A3	4.9E-12	4.0E-11	0	0
Am-241	A1	1.2E-11	1.2E-10	0	0
Cm-242	A1	1.3E-11	1.2E-10	0	0
Cm-244	A1	1.3E-11	1.2E-10	0	0
Cf-252	A1	4.6E-11	6.4E-10	0	0

Remarks: * For details of RBE-weighted absorbed dose estimation see Introduction to Appendix XII.

XII-D3. Data for evaluation the absorbed doses to organs and tissues of members of the public from ingestion intake of radionuclides

TABLE XII-D3-1. COMMITTED RBE-WEIGHTED ABSORBED DOSE PER UNIT INTAKE $Ad_{P,T}^{Ing}(g,\Delta)$ DELIVERED IN ORGAN OR TISSUE OF MEMBER OF THE PUBLIC OVER 30 DAYS AFTER ACUTE INGESTION INTAKE OF TRITIUM [Gy-Eq×Bq^{-1}]*

Compound	Age (g), a	Organ or tissue		
		Lung	Red marrow	Colon
OBT	Adults	2.1E-11	2.1E-11	2.2E-11
OBT	0.25	1.0E-10	1.0E-10	1.2E-10
OBT	1	8.8E-11	8.8E-11	1.0E-10
OBT	5	5.1E-11	5.1E-11	5.7E-11
OBT	10	3.5E-11	3.5E-11	3.9E-11
OBT	15	2.3E-11	2.3E-11	2.5E-11
HTO	Adults	1.5E-11	1.5E-11	1.5E-11
HTO	0.25	6.3E-11	6.3E-11	6.3E-11
HTO	1	4.7E-11	4.7E-11	4.7E-11
HTO	5	2.9E-11	2.9E-11	2.9E-11
HTO	10	2.1E-11	2.1E-11	2.1E-11
HTO	15	1.6E-11	1.6E-11	1.6E-11

Remarks: * For details of RBE-weighted absorbed dose estimation see Introduction to Appendix XII.

TABLE XII-D3-2. COMMITTED RBE-WEIGHTED ABSORBED DOSE PER UNIT INTAKE $Ad_{P,T}^{Ing}(g,\Delta)$ DELIVERED IN ORGAN OR TISSUE OF MEMBER OF THE PUBLIC OVER 30 DAYS AFTER ACUTE INGESTION INTAKE OF RADIONUCLIDES [Gy-Eq×Bq^{-1}]*

Radionuclide	Age (g), a	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
Fe-59	Adults	2.7E-10	7.7E-10	5.4E-09	0
Fe-59	0.25	9.9E-09	3.9E-08	3.2E-08	0
Fe-59	1	2.5E-09	8.0E-09	3.1E-08	0
Fe-59	5	1.4E-09	4.6E-09	1.7E-08	0
Fe-59	10	9.3E-10	2.7E-09	1.0E-08	0
Fe-59	15	6.3E-10	1.7E-09	6.2E-09	0
Co-57	Adults	1.4E-11	3.5E-11	8.9E-10	0
Co-57	0.25	5.3E-10	5.1E-10	5.1E-09	0
Co-57	1	2.0E-10	2.1E-10	4.9E-09	0
Co-57	5	1.1E-10	1.3E-10	2.5E-09	0
Co-57	10	7.0E-11	9.2E-11	1.6E-09	0
Co-57	15	4.6E-11	6.3E-11	9.2E-10	0
Co-58	Adults	7.6E-11	2.3E-10	2.7E-09	0
Co-58	0.25	2.4E-09	2.3E-09	1.3E-08	0
Co-58	1	9.6E-10	1.1E-09	1.3E-08	0
Co-58	5	5.3E-10	7.1E-10	7.1E-09	0
Co-58	10	3.5E-10	5.3E-10	4.5E-09	0
Co-58	15	2.4E-10	3.8E-10	2.8E-09	0

Radionuclide	Age (g), a	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
Co-60	Adults	2.1E-10	5.7E-10	6.9E-09	0
Co-60	0.25	6.5E-09	6.1E-09	3.5E-08	0
Co-60	1	2.6E-09	2.8E-09	3.3E-08	0
Co-60	5	1.4E-09	1.9E-09	1.8E-08	0
Co-60	10	9.4E-10	1.4E-09	1.2E-08	0
Co-60	15	6.4E-10	9.7E-10	7.2E-09	0
Sr-85	Adults	1.2E-10	3.7E-10	1.1E-09	0
Sr-85	0.25	2.4E-09	6.2E-09	6.4E-09	0
Sr-85	1	8.8E-10	1.9E-09	5.3E-09	0
Sr-85	5	4.5E-10	1.1E-09	3.0E-09	0
Sr-85	10	3.5E-10	1.0E-09	2.0E-09	0
Sr-85	15	2.9E-10	9.8E-10	1.3E-09	0
Sr-89	Adults	1.7E-10	2.0E-09	1.4E-08	0
Sr-89	0.25	2.4E-09	7.4E-08	9.6E-08	0
Sr-89	1	1.4E-09	1.7E-08	9.1E-08	0
Sr-89	5	7.4E-10	7.8E-09	4.6E-08	0
Sr-89	10	3.8E-10	6.5E-09	2.6E-08	0
Sr-89	15	1.8E-10	5.7E-09	1.4E-08	0
Sr-90	Adults	3.1E-10	4.0E-09	1.2E-08	0
Sr-90	0.25	4.3E-09	1.5E-07	8.5E-08	0
Sr-90	1	2.6E-09	3.3E-08	7.9E-08	0
Sr-90	5	1.3E-09	1.5E-08	4.0E-08	0
Sr-90	10	6.9E-10	1.3E-08	2.3E-08	0
Sr-90	15	3.3E-10	1.2E-08	1.2E-08	0
Ru-106	Adults	2.5E-10	2.8E-10	4.4E-08	0
Ru-106	0.25	5.4E-09	5.4E-09	4.9E-07	0
Ru-106	1	1.8E-09	1.8E-09	3.3E-07	0
Ru-106	5	8.7E-10	9.3E-10	1.6E-07	0
Ru-106	10	5.2E-10	5.7E-10	9.7E-08	0
Ru-106	15	3.1E-10	3.5E-10	5.5E-08	0
I-125	Adults	1.6E-11	1.3E-11	2.4E-11	1.2E-07
I-125	0.25	2.5E-10	1.1E-10	6.2E-10	8.3E-07
I-125	1	1.8E-10	7.4E-11	3.7E-10	8.5E-07
I-125	5	8.6E-11	3.8E-11	1.6E-10	5.2E-07
I-125	10	4.6E-11	2.4E-11	5.9E-11	2.8E-07
I-125	15	2.0E-11	1.6E-11	3.2E-11	1.9E-07
I-131	Adults	9.7E-11	9.5E-11	1.2E-10	8.0E-08
I-131	0.25	7.1E-10	5.1E-10	2.6E-09	7.2E-07
I-131	1	5.3E-10	3.6E-10	1.5E-09	7.0E-07
I-131	5	3.1E-10	2.1E-10	6.3E-10	4.0E-07
I-131	10	2.0E-10	1.5E-10	2.7E-10	2.0E-07

Radionuclide	Age (g), a	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
I-131	15	1.2E-10	1.1E-10	1.5E-10	1.2E-07
I-133	Adults	4.5E-11	4.7E-11	1.1E-10	8.2E-08
I-133	0.25	4.2E-10	3.7E-10	1.2E-09	9.6E-07
I-133	1	2.8E-10	2.5E-10	7.8E-10	8.6E-07
I-133	5	1.5E-10	1.3E-10	3.9E-10	4.6E-07
I-133	10	9.1E-11	8.5E-11	2.3E-10	2.0E-07
I-133	15	5.6E-11	5.6E-11	1.4E-10	1.3E-07
Cs-134	Adults	3.4E-09	3.6E-09	4.3E-09	0
Cs-134	0.25	1.7E-08	1.6E-08	2.9E-08	0
Cs-134	1	1.1E-08	1.0E-08	1.9E-08	0
Cs-134	5	6.8E-09	6.7E-09	1.1E-08	0
Cs-134	10	5.0E-09	5.1E-09	7.0E-09	0
Cs-134	15	4.0E-09	4.1E-09	4.7E-09	0
Cs-136	Adults	2.3E-09	2.4E-09	2.9E-09	0
Cs-136	0.25	1.2E-08	1.1E-08	1.9E-08	0
Cs-136	1	7.9E-09	7.4E-09	1.3E-08	0
Cs-136	5	4.8E-09	4.8E-09	7.5E-09	0
Cs-136	10	3.4E-09	3.5E-09	4.8E-09	0
Cs-136	15	2.6E-09	2.7E-09	3.2E-09	0
Cs-137	Adults	2.2E-09	2.3E-09	2.9E-09	0
Cs-137	0.25	1.3E-08	1.3E-08	2.8E-08	0
Cs-137	1	8.1E-09	7.9E-09	1.9E-08	0
Cs-137	5	4.8E-09	4.8E-09	9.6E-09	0
Cs-137	10	3.4E-09	3.5E-09	5.7E-09	0
Cs-137	15	2.6E-09	2.6E-09	3.4E-09	0
Ra-226	Adults	9.8E-10	7.4E-09	0	0
Ra-226	0.25	2.8E-08	6.5E-07	0	0
Ra-226	1	1.0E-08	8.5E-08	0	0
Ra-226	5	4.9E-09	3.8E-08	0	0
Ra-226	10	2.9E-09	3.6E-08	0	0
Ra-226	15	1.6E-09	3.7E-08	0	0
Ra-228	Adults	9.5E-11	6.0E-10	0	0
Ra-228	0.25	3.9E-09	5.5E-08	0	0
Ra-228	1	1.1E-09	7.2E-09	0	0
Ra-228	5	4.9E-10	3.2E-09	0	0
Ra-228	10	3.5E-10	3.0E-09	0	0
Ra-228	15	2.5E-10	3.0E-09	0	0
Th-228	Adults	2.1E-10	1.2E-09	0	0
Th-228	0.25	1.0E-08	1.6E-07	0	0
Th-228	1	1.9E-09	1.3E-08	0	0
Th-228	5	9.1E-10	5.9E-09	0	0

Radionuclide	Age (g), a	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
Th-228	10	5.3E-10	4.3E-09	0	0
Th-228	15	2.8E-10	3.4E-09	0	0
Th-232	Adults	1.8E-11	1.8E-10	0	0
Th-232	0.25	1.5E-09	3.6E-08	0	0
Th-232	1	9.5E-11	2.1E-09	0	0
Th-232	5	4.6E-11	9.8E-10	0	0
Th-232	10	2.8E-11	5.1E-10	0	0
Th-232	15	1.6E-11	3.0E-10	0	0
U-234	Adults	2.5E-10	8.1E-10	0	0
U-234	0.25	4.2E-09	3.3E-08	0	0
U-234	1	1.6E-09	5.5E-09	0	0
U-234	5	8.1E-10	2.6E-09	0	0
U-234	10	4.6E-10	2.1E-09	0	0
U-234	15	2.3E-10	1.9E-09	0	0
U-235	Adults	2.3E-10	7.6E-10	0	0
U-235	0.25	3.9E-09	3.0E-08	0	0
U-235	1	1.5E-09	5.1E-09	0	0
U-235	5	7.7E-10	2.4E-09	0	0
U-235	10	4.2E-10	2.0E-09	0	0
U-235	15	2.2E-10	1.7E-09	0	0
U-238	Adults	2.2E-10	7.2E-10	0	0
U-238	0.25	3.5E-09	2.9E-08	0	0
U-238	1	1.4E-09	4.9E-09	0	0
U-238	5	7.0E-10	2.3E-09	0	0
U-238	10	3.9E-10	1.9E-09	0	0
U-238	15	2.1E-10	1.7E-09	0	0
Np-237	Adults	1.5E-11	1.6E-10	0	0
Np-237	0.25	1.6E-09	2.7E-08	0	0
Np-237	1	1.1E-10	1.6E-09	0	0
Np-237	5	5.3E-11	8.1E-10	0	0
Np-237	10	3.2E-11	4.2E-10	0	0
Np-237	15	1.9E-11	2.5E-10	0	0
Pu-238	Adults	2.7E-11	2.1E-10	0	0
Pu-238	0.25	2.9E-09	4.2E-08	0	0
Pu-238	1	1.9E-10	2.5E-09	0	0
Pu-238	5	9.5E-11	9.9E-10	0	0
Pu-238	10	5.6E-11	5.2E-10	0	0
Pu-238	15	3.3E-11	3.0E-10	0	0
Pu-239, Pu-240	Adults	2.5E-11	2.0E-10	0	0
Pu-239, Pu-240	0.25	2.8E-09	4.0E-08	0	0
Pu-239, Pu-240	1	1.8E-10	2.3E-09	0	0

Radionuclide	Age (g), a	Organ or tissue			
		Lung	Red marrow	Colon	Thyroid
Pu-239, Pu-240	5	8.8E-11	9.3E-10	0	0
Pu-239, Pu-240	10	5.3E-11	4.9E-10	0	0
Pu-239, Pu-240	15	3.1E-11	2.8E-10	0	0
Am-241	Adults	1.3E-11	1.2E-10	0	0
Am-241	0.25	1.3E-09	4.6E-08	0	0
Am-241	1	8.8E-11	2.7E-09	0	0
Am-241	5	4.2E-11	8.9E-10	0	0
Am-241	10	2.6E-11	4.7E-10	0	0
Am-241	15	1.5E-11	2.7E-10	0	0
Cm-242	Adults	1.3E-11	1.2E-10	0	0
Cm-242	0.25	1.4E-09	4.8E-08	0	0
Cm-242	1	9.1E-11	2.8E-09	0	0
Cm-242	5	4.6E-11	9.3E-10	0	0
Cm-242	10	2.7E-11	4.9E-10	0	0
Cm-242	15	1.6E-11	2.8E-10	0	0
Cm-244	Adults	1.3E-11	1.2E-10	0	0
Cm-244	0.25	1.4E-09	4.8E-08	0	0
Cm-244	1	9.1E-11	2.8E-09	0	0
Cm-244	5	4.6E-11	9.4E-10	0	0
Cm-244	10	2.7E-11	4.9E-10	0	0
Cm-244	15	1.6E-11	2.9E-10	0	0
Cf-252	Adults	4.6E-11	6.4E-10	0	0
Cf-252	0.25	1.1E-09	8.8E-08	0	0
Cf-252	1	4.6E-10	5.5E-09	0	0
Cf-252	5	2.0E-10	2.7E-09	0	0
Cf-252	10	1.1E-10	1.5E-09	0	0
Cf-252	15	6.7E-11	8.9E-10	0	0

Remark: * For details of estimation an RBE-weighted absorbed doses see the Introduction to Appendix XII.

TABLE XII-D3-3. COMMITTED RADIATION WEIGHTED DOSE PER UNIT INTAKE $h_{P,T}^{Ing}(g,\tau)$ DELIVERED IN THYROID OF MEMBER OF THE PUBLIC AFTER ACUTE INGESTION INTAKE OF THYROID SEEKING RADIONUCLIDES [Sv×Bq^{-1}], [57]

Age (g), a	Radionuclide		
	I-125	I-131	I-133
Adults	3.0E-07	4.3E-07	8.2E-08
0.25	1.0E-06	3.7E-06	9.6E-07
1	1.1E-06	3.6E-06	8.6E-07
5	8.2E-07	2.1E-06	4.6E-07
10	6.2E-07	1.0E-06	2.0E-07
15	4.4E-07	6.8E-07	1.3E-07

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ABRIDGEMENTS AND SYMBOLS

Abridgements and symbols	Description
g	Age characterizing the Reference Man as a representative member of the certain age cohort of the public.
τ	Parameter for estimation the committed weighted and committed effective doses of internal exposure. It should be taken to be 50 years for adults and up to the age of 70 years for intakes by children.
Δ	Time after short time (acute) intake of radionuclide for assessment the RBE-weighted absorbed dose of internal exposure.
$Ad^{Ing}_{W,offspring}(\Delta)$	Committed RBE-weighted absorbed dose per unit ingestion intake of female Reference Worker delivered in the offspring over definite time Δ after acute intake [Gy-Eq×Bq^{-1}].
$Ad^{Inh}_{W,offspring}(\Delta)$	Committed RBE-weighted absorbed dose per unit inhalation intake of female Reference Worker delivered in the offspring over definite time Δ after acute intake [Gy-Eq×Bq^{-1}].
$Ad^{Ing}_{W,T}(\Delta)$	Committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue *T* of Reference Worker over definite time Δ after acute ingestion intake [Gy-Eq×Bq^{-1}].
$Ad^{Inh}_{W,T}(\Delta)$	Committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue *T* of Reference Worker over definite time Δ after acute inhalation intake [Gy-Eq×Bq^{-1}].
$Ad^{Ing}_{P,T}(g,\Delta)$	Committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue *T* of Reference Member of the Public with age *g* over definite time Δ after acute ingestion intake [Gy-Eq×Bq^{-1}].
$Ad^{Inh}_{P,T}(g,\Delta)$	Committed RBE-weighted absorbed dose per unit intake delivered in organ or tissue *T* of Reference Member of the Public with age *g* over definite time Δ after acute inhalation intake [Gy-Eq×Bq^{-1}].
$e^{Ing}_{W}(\tau)$	Committed effective doses per unit intake from ingestion intake of radionuclides by Reference Worker [Sv×Bq^{-1}].
$e^{Inh}_{W}(\tau)$	Committed effective doses per unit intake from inhalation intake of radionuclides by Reference Worker [Sv×Bq^{-1}].
$e^{Ing}_{P}(g,\tau)$	Committed effective doses per unit intake from ingestion intake of radionuclides by Reference Member of the Public with age *g* [Sv×Bq^{-1}].
$e^{Inh}_{P}(g,\tau)$	Committed effective doses per unit intake from inhalation intake of radionuclides by Reference Member of the Public with age *g* [Sv×Bq^{-1}].
σ_g	Standard geometrical deviation of the distribution of activity of aerosol over the aerodynamic diameter of its particles.

ABBREVIATIONS USED IN THIS PUBLICATION

Abbreviations	Description
ARS	acute radiation syndrome
BSS	Basic Safety Standards
CBC	cell blood count
ERC	Emergency Response Centre
HTO	tritiated water
ICP-AES	inductively coupled plasma atomic emission spectrometry
ICP-MS	inductively coupled plasma mass spectrometry
ICS	incident command system
LRI	local radiation injury
NPP	nuclear power plant
NRBC	nuclear radiological biological chemical
NREP	national radiation emergency plan
OBT	organically bound tritium
PAZ	precautionary action zone
RBE	relative biological effectiveness of radiation
RM	red marrow
SIl	international system of units
TLD	thermoluminescent dosimeter/dosimetry
TSH	thyroid stimulating hormone
UPZ	urgent protective action planning zone
WB	whole body

DEFINITIONS

absorbed dose, D

The fundamental dosimetric quantity *D*, defined as:

$$D = \frac{d\bar{\varepsilon}}{dm}$$

where $d\bar{\varepsilon}$ is the mean energy imparted by *ionizing radiation* to matter in a volume element and *dm* is the mass of matter in the volume element. The unit of absorbed dose is J/kg, termed the *gray* (*Gy*).

accident

Any unintended event, including operating errors, equipment failures or other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection or safety.

action level

The level of dose rate or activity concentration above which remedial actions or protective actions should be carried out in chronic exposure or emergency exposure situations. An action level can also be expressed in terms of any other measurable quantity as a level above which intervention should be undertaken.

acute exposure

Exposure received within a short period of time.

- Normally used to refer to *exposure* of sufficiently short duration that the resulting *doses* can be treated as instantaneous (e.g. less than an hour).

acute intake

An *intake* occurring within a time period short enough that it can be treated as instantaneous for the purposes of assessing the resulting *committed dose*.

annual dose

The *dose* due to *external exposure* in a year plus the *committed dose* from intakes of radionuclides in that year.

- This is not, in general, the same as the dose actually delivered during the year in question, which could include doses from radionuclides remaining in the body from intakes in previous years, and could exclude doses delivered in future years from intakes during the year in question.

becquerel (Bq)

Name for the SI unit of activity, equal to one transformation per second.

- Supersedes the *curie (Ci)*. 1 Bq = 27 pCi ($2.7\ 10^{-11}$ Ci) approximately.

bioassay

Any procedure used to determine the nature, activity, location or retention of radionuclides in the body by direct (in-vivo) measurement or by in-vitro analysis of material excreted or otherwise removed from the body.

biological half-life

The time taken for the quantity of a material in a specified tissue, organ or region of the body (or any other specified biota) to halve as a result of biological processes.

child

In dosimetry (e.g. in tables of dose per unit intake values), a *child* is often assumed to be a 10 year-old. If such an assumption is made, it should be clearly stated. See also *infant*.

chronic exposure

Exposure persisting in time.

- Normally used to refer to *exposures* persisting for many years as a result of long lived radionuclides in the environment. *Exposure* that is too protracted to be described as *acute exposure*, but does not persist for many years, is sometimes described as *transitory exposure*.

chronic intake

An *intake* over an extended period of time, such that it cannot be treated as a single instantaneous *intake* for the purposes of assessing the resulting *committed dose*: $S = \sum_i E_i \cdot N_i$

colon

Part of the gastrointestinal tract consists of Upper and Lover Large Intestine.

committed absorbed dose, $D_T(\tau)$

The quantity $D_T(\tau)$, used as characteristic of internal exposure and defined as:

$$D_T(\tau) = \int_{t_0}^{t_0+\tau} \dot{D}_T(t)\, dt$$

where t_0 is the time of *intake*, $\dot{D}_T(t)$ is the *organ dose rate* at time t in organ or tissue T and τ is the time elapsed after an *intake* of radioactive substances.

- For intake of radioactive material, a committed absorbed dose characterizes internal irradiation of organs and tissues of an individual according to its distribution in the body of *reference man* which would occur after the same intake.

committed effective dose, $E(\tau)$

The quantity $E(\tau)$, used as characteristic of internal exposure and defined as:

$$E(\tau) = \sum_T w_T \times H_T(\tau)$$

where $H_T(\tau)$ is the *committed radiation weighted dose* to tissue T over the integration time τ and w_T is the tissue weighting factor for tissue T. When τ is not specified, it will be taken to be 50 years for adults and up to the age of 70 years for *intakes* by children.

committed radiation weighted dose, $H_T(\tau)$

The quantity $H_T(\tau)$, used as characteristic of internal exposure and defined as:

$$H_T(\tau) = \int_{t_0}^{t_0+\tau} \dot{H}_T(t)\, dt$$

where t_0 is the time of *intake*, $\dot{H}_T(t)$ is the *radiation weighted dose rate* at time t in organ or tissue T and τ is the time elapsed after an *intake* of radioactive substances. When τ is not specified, it will be taken to be 50 years for adults and up to the age of 70 years for *intakes* by children.

- For intake of radioactive material, a committed radiation weighted dose characterizes internal irradiation of organs and tissues of an individual according to quality of radiation and to its distribution in the body of *reference man* which would occur after the same intake.

committed RBE-weighted absorbed dose, $AD_T(\tau)$

The quantity $AD_T(\tau)$, used as characteristic of internal exposure and defined as:

$$AD_T(\tau) = \int_{t_0}^{t_0+\tau} \dot{AD}_T(t)\, dt$$

where t_0 is the time of *intake*, $\dot{AD}_T(t)$ is the *RBE-weighted absorbed dose rate* at time t in organ or tissue T and τ is the time elapsed after an *intake* of radioactive substances.

- For intake of radioactive material, a committed RBE-weighted absorbed dose characterizes internal irradiation of organs and tissues of an individual according to quality of radiation and to its distribution in the body of *reference man* which would occur after the same intake.

contamination

Radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where their presence, or the process giving rise to their presence, is unintended or undesirable.

dangerous source

A source that could, if not under control, give rise to exposure sufficient to cause severe deterministic effects. The categorization is used for determining the need for emergency response arrangements and is not to be confused with categorization of sources for other purposes.

decontamination

The complete or partial removal of *contamination* by a deliberate physical, chemical or biological process.

- This definition is intended to include a wide range of processes, but to exclude the removal of radionuclides from within the human body, which is not considered to be *decontamination*.

decontamination factor

The ratio of the activity per unit area (or per unit mass or volume) before a particular *decontamination* technique is applied to the activity per unit area (or per unit mass or volume) after application of the technique.

decorporation

Process of treatment for persons with internally deposited radionuclides aimed to reduce the internal dose of exposure and hence the risk of health effects. Can be accomplished by reducing absorption, preventing incorporation and internal deposition of radionuclides within organs, and promoting elimination or excretion of absorbed nuclides.

deterministic effect

A health effect of radiation for which, generally, a threshold level of dose exists above which the severity of the effect is greater for a higher dose. Such an effect is described as a 'severe deterministic effect' if it is fatal or life threatening or results in a permanent injury that reduces the quality of life.

dose

A measure of the energy deposited by *radiation* in a target.

dose assessment

Assessment of the *dose(s)* to an individual or group of people.

dose rate

The time derivative of *dose*, $\dot{D}=\frac{dD}{dt}$, where dD is the increment of *dose* in the time interval dt.

- Although dose rate could, in principle, be defined over any unit of time (e.g. an annual dose is, technically a dose rate), in IAEA documents the term *dose rate* should be used only in the context of short periods of time, e.g. dose per second or dose per hour.

effective dose, *E*

The quantity E, defined as a summation of the tissue *radiation weighted doses*, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_T w_T \times H_T$$

where H_T is the *weighted dose* in tissue T and w_T is the *tissue weighting factor* for tissue T. From the definition of *radiation weighted dose*, it follows that:

$$E = \sum_T w_T \times \sum_R w_R \times D_{R,T}$$

where w_R is the radiation weighting factor for *radiation* R and $D_{T,R}$ is the average *absorbed dose* in the organ or tissue T.

- The unit of effective dose is J/kg, termed the *sievert* (*Sv*).
- *Effective dose* is a measure of *dose* designed to reflect the amount of radiation detriment likely to result from the *dose*.
- Values of *effective dose* from any type(s) of *radiation* and mode(s) of *exposure* can be compared directly.
- Effective dose is intended to account for differences in biological effectiveness in producing harm, due to the quality of radiation and its distribution in the body of *reference man*.
- Effective dose is intended for use as a radiation protection quantity and therefore should not be used for epidemiological evaluations, nor should it be used for any specific investigation of human exposure.

effective half-life, T_{eff}

The time taken for the *activity* of a radionuclide in a specified place to halve as a result of all relevant processes.

$$T_{eff} = \frac{\prod_i T_i}{\sum_i T_i} \text{ (or } \frac{1}{T_{eff}} = \sum_i \frac{1}{T_i}\text{)},$$

where T_i is the *half-life* for process i.

emergency

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

emergency exposure

Exposure received during an emergency situation. This may include unplanned *exposures* resulting directly from the emergency and planned *exposures* to persons undertaking actions to mitigate the emergency.

emergency classification

The process whereby an authorized official classifies an emergency in order to declare the applicable emergency class. Upon declaration of the emergency class, the response organizations initiate the predefined response actions for that emergency class.

emergency preparedness

The capability to take actions that will effectively mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment.

emergency procedures

A set of instructions describing in detail the actions to be taken by response personnel in an emergency.

emergency response

The performance of actions to mitigate the consequences of an emergency for human health and safety, quality of life, property and the environment. It may also provide a basis for the resumption of normal social and economic activity.

emergency services

The local off-site response organizations that are generally available and that perform emergency response functions. These may include police, fire and rescue brigades, ambulance services, and control teams for hazardous materials.

emergency worker

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, quality of life, property and the environment.

emergency zones

The precautionary action zone and/or the urgent protective action planning zone.

environmental monitoring

The measurement of *external dose* rates due to sources in the environment or of radionuclide concentrations in environmental media.

equivalent dose in organ or tissue, H_T

see *radiation weighted dose in organ or tissue.*

exposure

The act or condition of being subject to irradiation. *Exposure* can be either external exposure (due to a source outside the body), or internal exposure (due to a source within the body).

exposure pathway

A route by which *radiation* or *radionuclides* can reach humans and cause *exposure*.

- An *exposure pathway* may be very simple, e.g. *external exposure* from airborne radionuclides, or a more complex chain, e.g. *internal exposure* from drinking milk from cows that ate grass contaminated with deposited radionuclides.

external exposure

Exposure due to a source outside the body.

extrathoracic airways

Part of the respiratory system (lung) placed outside the thorax (see Figure XII-1.). It includes [59]:

- anterior nasal passage;
- posterior nasal and oral passages, the pharynx and larynx;
- lymphatic tissue associated with the extrathoracic airways.

field decontamination

Decontamination at the scene of radiation emergency. As this activity needs to be quick, simple and effective, it usually includes the following as possible: removal of outer closing, washing of face and hands, covering of victim in the blanket. Further decontamination is usually applied at the later stage of response.

field triage

Triage at the scene of radiation emergency. See *triage* for details.

first responders

The first members of an emergency service to respond at the scene of an emergency.

fixed contamination

Contamination other than *non-fixed contamination*.

gray (Gy)

Name for the SI unit of kerma and *absorbed dose*, equal to 1 J/kg.

gray-equivalent (Gy-Eq)

Name for the unit of *RBE-weighted absorbed dose*.

hereditary effect

A *radiation*-induced health effect that occurs in a descendant of the exposed person.

- The less precise term ‘genetic effect’ is also used, but *hereditary effect* is preferred.
- *Hereditary effects* are normally *stochastic effects*.

individual dose

The *dose* incurred by an individual.
The value of an individual dose:

- is attributed to the person in question through *individual monitoring.*
- should be determined as a dose to *reference worker,* who would work with a given source in the same way and under the same working conditions as the worker in question.

The possible difference of an individual dose from a true dose of an exposure to the individual, caused by distinction between characteristics of *reference worker* and personal biological characteristics of the individual should be ignored.

individual (personal) monitoring

Monitoring using measurements by equipment worn by individual workers, or measurements of quantities of radioactive materials in or on their bodies.

infant

In dosimetry, unless otherwise stated, an *infant* is assumed to be a one-year-old, and annual quantities (e.g. *annual dose*, annual *intake*) relating to an *infant* refer to the year starting at birth.

intake

The activity of a radionuclide taken into the body by inhalation or ingestion or through the skin in a given time period or as a result of a given event. Intake could be *acute* or *chronic*.

internal exposure

Exposure due to a source within the body.

intervention

Any action intended to reduce or avert *exposure* or the likelihood of *exposure* to sources which are not part of a controlled practice or which are out of control as a consequence of an *accident*.

intervention level

The level of avertable dose at which a specific protective action is taken in an emergency or situation of chronic exposure.

iodine prophylaxis

The administration of a compound of stable iodine (usually potassium iodide) to prevent or reduce the uptake of radioactive isotopes of iodine by the thyroid in the event of an *accident* involving radioactive iodine.

- The terms ‘thyroid blocking’ or ‘iodine blockade’ are sometimes used.

ionizing radiation

For the purposes of radiation protection, radiation capable of producing ion pairs in biological material(s).

lifetime dose

The total *dose* received by an individual during his/her lifetime.

- In practice, often approximated as the sum of the *annual doses* incurred. Because *annual doses* include *committed doses*, some parts of some of the *annual doses* may not actually be delivered within the lifetime of the individual, and therefore this may overestimate the true *lifetime dose*.
- For prospective assessments of *lifetime dose*, a lifetime is normally interpreted as 70 years.

mass casualty event

Any event resulting in number of victims large enough to disrupt the normal course of emergency and health care services.

medical exposure

Exposure incurred by patients as part of their own medical or dental diagnosis (*diagnostic exposure*) or treatment (*therapeutic exposure*); by persons, other than those occupationally exposed, knowingly exposed while voluntarily helping in the support and comfort of patients; and by volunteers in a programme of biomedical research involving their *exposure*.

medical practitioner

An individual who: (a) has been accredited through appropriate national procedures as a health professional; (b) fulfils the national requirements on training and experience for prescribing procedures involving *medical exposure*; and (c) is a registrant or a licensee, or a worker who has been designated by a registered or licensed employer for the purpose of prescribing procedures involving *medical exposure*.

monitoring

The measurement of *dose* or *contamination* for reasons related to the assessment or control of *exposure* to *radiation* or radioactive substances, and the interpretation of the results. See also *environmental monitoring*, *individual (personal) monitoring*, and *source monitoring*.

natural exposure

Exposure due to natural sources.

non-fixed contamination

Contamination that can be removed from a surface during routine conditions of transport.

non-radiological consequences

Effects on humans or the environment that are not deterministic or stochastic effects of radiation. These include effects on health or quality of life resulting from the psychological, social, or economic impact resulting from the emergency or the response to the emergency.

nuclear emergency

An emergency for which the principal cause of the actual or perceived hazard:
(1) involves a nuclear chain reaction; or
(2) involves the energy resulting from a chain reaction or from the decay of the products of a chain reaction.

offspring

Collective term used in this manual for dose assessment for the embryo, foetus, and newborn child.

operational intervention level (OIL)

A calculated level, measured by instruments or determined by laboratory analysis, that corresponds to an intervention level or action level. OILs are typically expressed in terms of dose rates or of activity of radioactive material released, time integrated air concentrations, ground or surface concentrations, or activity concentrations of radionuclides in environmental, food or water samples. An OIL is a type of action level that is used immediately and directly (without further assessment) to determine the appropriate protective actions on the basis of an environmental measurement.

organ dose, D_T

The mean *absorbed dose* in a specified tissue or organ T of the human body, given by:

$$D_T = \frac{1}{m_T} \int_{m_T} D \, dm$$

where m_T is the mass of the tissue or organ and D is the *absorbed dose* in the mass element dm.

precautionary action zone

An area around a facility for which arrangements have been made to take urgent protective actions in the event of a nuclear or radiological emergency to reduce the risk of severe deterministic health effects off the site. Protective actions within this area are to be taken before or shortly after a release of radioactive material or an exposure on the basis of the prevailing conditions at the facility.

public exposure

Exposure incurred by members of the public from radiation sources, excluding any *occupational* or *medical exposure* and the normal local natural background radiation but including *exposure* from authorized sources and *practices* and from *intervention* situations.

radiation weighted dose in organ or tissue, H_T

The quantity H_T, defined as:

$$H_T = \sum_R w_R \times D_{R,T}$$

where $D_{T,R}$ is the *organ dose* delivered by *radiation* type R to organ or tissue T and w_R is the *radiation weighting factor* for *radiation* type R. The unit of radiation weighted dose is J/kg, termed the *sievert* (*Sv*).
It is a measure of the *dose* to a tissue or organ designed to reflect the amount of harm caused.

- The values of a *radiation weighted dose* to a specified tissue from any type of radiation can therefore be compared directly.
- The radiation weighted dose is intended to account for differences in biological effectiveness in producing stochastic health effects in organs or tissues of *reference man* due to the quality of radiation.

radioactive (physical) half-life, $T_{½}$

For a radionuclide, the time required for the activity to decrease, by a radioactive decay process, by half.

- The *half-life* is related to the decay constant, λ, by the expression: $T_{1/2} = \frac{\ln 2}{\lambda}$

radiation emergency

A nuclear or radiological emergency.

radiological emergency

An emergency that is not a nuclear emergency and for which the principal actual or perceived hazard is ionizing radiation.

radiological dispersal device (RDD)

A device constructed by terrorists to spread radioactive materials using conventional explosives or other means.

RBE-weighted absorbed dose

A product of the absorbed dose in an organ or tissue and the RBE of radiation:

$$AD_T = \sum_R D_{R,T} \times RBE_{R,T} ,$$

where $D_{R,T}$ is the *organ dose* from radiation R in tissue T and $RBE_{R,T}$ is the relative biological effectiveness of radiation R in producing a specific effect in a particular organ or tissue (T). The unit of RBE-weighted absorbed dose is $J \times kg^{-1}$, termed the *gray-equivalent* (*Gy-Eq*).

- The RBE-weighted absorbed dose is intended to account for differences in biological effectiveness in producing deterministic health effects in organs or tissues of *reference man* due to the quality of radiation.

red marrow

Red Bone Marrow (active) - the component of marrow which contains the bulk of the haematopoetic stem cells.

reference man

An adult human with the anatomical and physiological characteristics defined in the report of the ICRP Task Group on Reference Man [60].

reference worker

An adult worker with the anatomical and physiological characteristics defined in the report of the ICRP Task Group on Reference Man [60].

relative biological effectiveness (RBE)

For a particular organ or tissue (T), the $RBE_{R,T}$ is the ratio of the absorbed dose of reference radiation that produces a specified biological effect relative to the absorbed dose of the radiation of interest (R) that produces the same biological effect.

In general, the RBE for biological effects of radiation depends on such factors as the quality of radiation, irradiated organ or tissue, committed effect, and a dose rate. Values of the RBE of radiation for severe deterministic health effects used in this manual are the listed below.

RBE of radiation for severe deterministic effects used in the manual

Radiation	RBE
Photons (gamma- and X rays)	1
Electrons and positrons, including β^- and β^+ particles	1
Neutrons	3
Alpha particles irradiating internally lung	7
Alpha particles irradiating internally red marrow	2
Alpha particles irradiating internally colon	0
Iodine-131 irradiating internally thyroid gland	0.2
Alpha particles irradiating offspring	10

response organization

An organization designated or otherwise recognized by a State as being responsible for managing or implementing any aspect of a response.

sievert (Sv)

Name for the SI unit of *radiation weighted dose, dose equivalent* and *effective dose*, equal to 1 J/kg.

somatic effect

A *radiation*-induced health effect that occurs in the exposed person.

source

Anything that may cause radiation exposure — such as by emitting ionizing radiation or by releasing radioactive substances or materials — and can be treated as a single entity for protection and safety purposes. For example, materials emitting radon are sources in the environment, a sterilization gamma irradiation unit is a source for the practice of radiation preservation of food, an X ray unit may be a source for the practice of radiodiagnosis; a nuclear power plant is part of the practice of generating electricity by nuclear fission, and may be regarded as a source (e.g. with respect to discharges to the environment) or as a collection of sources (e.g. for occupational radiation protection purposes). A complex or multiple installations situated at one location or site may, as appropriate, be considered a single source for the purposes of application of international safety standards.

stochastic effect (of radiation)

A radiation induced health effect, the probability of occurrence of which is greater for a higher radiation dose and the severity of which (if it occurs) is independent of dose. Stochastic effects may be somatic effects or hereditary effects, and generally occur without a threshold level of dose. Examples include thyroid cancer and leukaemia.

thoracic lung

Part of the respiratory system (lung) placed inside the thorax (see Figure AXII.1). It includes [58]:

- bronchial region of respiratory system (trachea, main bronchi and bronchi);
- bronchiolar region of respiratory system (bronchioles and terminal bronchioles);
- alveolar-interstitial the gas exchange region(respiratory bronchioles and alveolar duct + alveoli);
- lymphatic tissue associated with the thoracic airways.

torso RBE-weighted absorbed dose

The mean RBE-weighted absorbed dose in a torso of *reference man* irradiated in uniform field of penetrating radiation, given by:

$$AD_{Torso} = \frac{1}{m_{Torso}} \int_{m_{Torso}} AD \, dm$$

where m_{Torso} is the mass of the body of *reference man* and *AD* is the *RBE-weighted absorbed dose* in the mass element *dm*.

Torso RBE-weighted absorbed dose is used to address external exposure to the lung, red marrow, small intestine, gonads, thyroid and lens of eye when body of *reference man* is in a uniform field of strongly penetrating radiation. This would also be the dose of strongly penetrating radiation typically monitored by a personal dosimeter**.**

triage

Rapid method utilizing simple procedures to sort persons into groups based on their injury and/or disease for the purpose of expediting clinical care and maximizing the use of the available clinical services and facilities.

urgent protective action

A protective action in the event of an emergency which must be taken promptly (normally within hours) in order to be effective, and the effectiveness of which will be markedly reduced if it is delayed. The most commonly considered urgent protective actions in a nuclear or radiological emergency are evacuation, decontamination of individuals, sheltering, respiratory protection, iodine prophylaxis, and restriction of the consumption of potentially contaminated foodstuffs.

worried-well

A person who has received neither sufficient radiation exposure nor been sufficiently contaminated to warrant medical treatment or decontamination but who is worried and wishes to be assessed for radiation exposure/contamination.

whole body

All organs and tissues of the human body when they are uniformly irradiated (term to be used in dose assessment).

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