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Australian Radiation Protection and Nuclear Safety Agency

TECHNICAL REPORT

Environmental Monitoring Handbook for Visits by Nuclear Powered Warships

Part A

Monitoring for Post Accident Recovery

prepared by Stephen B Solomon

on behalf of the
Visiting Ships Panel (Nuclear)
Department of Defence

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Notice

Abstract

This handbook (referred to as the *Environmental Monitoring Handbook* in the text) provides guidelines for planning the emergency monitoring response to radiological emergencies associated with visits by Nuclear Powered Warships (NPW) in Australian ports, particularly in the later and recovery phases. The handbook provides organizational specifications, technical information and procedures for radiological monitoring, environmental sampling and laboratory analysis in response to a radiological emergency, and supplements the planning and organizational details in current radiation emergency planning documents.

The approach taken in planning for environmental monitoring for an NPW accident is based on the IAEA-TECDOC 955, *Generic Assessment Procedures for Determining Protective Actions during a Reactor Accident,* with the monitoring procedures based on IAEA-TECDOC 1092, *Generic Procedures for Environmental and Source Monitoring during a Radiological Emergency*, adapted to the Australian context.

The *Environmental Monitoring Handbook* is comprised of two parts. Part A, this document, provides an overview of post accident environmental monitoring and the guidelines for the decision making for the implementation of protective measures. Part B of the Handbook is team specific, that is, it provides the tasks, procedures and worksheets for the teams involved in the environmental monitoring response for the post NPW accident recovery.

Environmental Monitoring Handbook for Visits by Nuclear Powered Warships

Part A

Monitoring for Post Accident Recovery

Contents

1 Introduction

1.1 Scope

This handbook (referred to as the *Environmental Monitoring Handbook* in the text) provides guidelines for planning the emergency monitoring response to radiological emergencies associated with visits by NPWs in Australian ports, particularly in the later and recovery phases. The handbook provides organizational specifications, technical information and procedures for radiological monitoring, environmental sampling and laboratory analysis in response to a radiological emergency, and supplements the planning and organizational details in current radiation emergency planning documents.

An inter-departmental committee, the Visiting Ships Panel (Nuclear) (VSP(N)), oversees the arrangements for visits to Australian ports by Nuclear Powered Warships (NPW). These include the Commonwealth Plan *OPSMAN1* [(1)] dealing with visits by Nuclear Powered Warships, and the associated *Radiation Monitoring Handbook for Visits by Nuclear Powered Warships to Australian Ports*[(2)] and the Department of Defence document *Environmental Radiation Monitoring During Visits by NPWs to Australian Ports: Requirements, Arrangements and Procedures*[(3]
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1.2 Objectives

The objectives of emergency monitoring are to:

(a) provide accurate and timely data on the level and degree of hazards resulting from a radiological emergency
(b) provide detail of the physical and chemical characteristics of the hazard
(c) determine the extent and duration of the hazard
(d) assist decision makers on the need to take protective actions and interventions on the basis of operational intervention levels (OILs)
(e) confirm the efficiency of remedial measures such as decontamination procedures
(f) assist in preventing the spread of contamination
(g) provide information for accident classification
(h) provide information for protection of emergency workers

The *Environmental Monitoring Handbook* aims to address these objectives in the context of a radiation release associated with a visiting Nuclear Powered Warship in an Australian port. It provides the recommendations on procedures for sample collection and analysis and the basis for the training of the relevant monitoring teams.

The approach taken in planning for environmental monitoring for an NPW accident is based on the IAEA-TECDOC 955, *Generic Assessment Procedures for Determining Protective Actions during a Reactor Accident*[(4)], with the monitoring procedures based on IAEA-TECDOC 1092, *Generic Procedures for Environmental and Source Monitoring during a Radiological Emergency*[(5)], adapted to the Australian context.

1.3 Structure

The *Environmental Monitoring Handbook* is comprised of two parts. Part A provides an overview of post accident environmental monitoring and the guidelines for the decision making for the implementation of protective measures. Part B of the Handbook is team specific, that is, it provides the tasks, procedures and worksheets for the teams involved in the environmental monitoring response for the post NPW accident recovery. In addition to the Radiation Monitoring Groups defined in the *Radiation Monitoring Handbook for Visits by Nuclear Powered Warships to Australian Ports* [(2)] the four additional teams are defined to support the longer term recovery. These are:

(1) Environmental Survey Team (EST)
(2) Radiation Analysis Team (RAT)
(3) Analysis and Assessment Team (AAT)
(4) Laboratory Analysis Team (LAT)

2 Emergency Planning for Nuclear Powered Warships

2.1 OPSMAN1

The Commonwealth planning covering visits by visiting nuclear powered vessels is detailed in *OPSMAN1* [(1)]. *OPSMAN1* provides detailed information on the conditions, procedures and the responsibilities for the visits by nuclear-powered vessels to Australian ports. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), the Australian Nuclear Science and Technology Organization (ANSTO) and the Australian Defence Forces (ADF) are the main Commonwealth agencies providing radiological support to the emergency plans. The coordination of the Commonwealth response is the responsibility of Emergency Management Australia (EMA).

In the event of a reactor-based accident, procedures are in place to ensure the early removal of the damaged vessel from the port, thus removing the radiation source term. The immediate monitoring response to a nuclear powered warship accident is provided by the Radiation Monitoring Groups, comprising Commonwealth experts and State radiation health and emergency services personal. The arrangements for the immediate phase are detailed in the *Radiation Monitoring Handbook for Visits by Nuclear Powered Warships to Australian Ports* [(2)] and the Department of Defence document *Environmental Radiation Monitoring During Visits by NPWs to Australian Ports: Requirements, Arrangements and Procedures* [(3)]

The relevant sections of OPSMAN1 dealing with longer-term radiation monitoring state:

> **OPSMAN1, Section 31.** *Following the immediate post-accident radiation monitoring period, more extensive environmental radiation monitoring is to be undertaken to:*
> a. *determine the extent of any decontamination needed,*
> b. *monitor drinking water and foodstuffs that may have been affected,*
> c. *monitor the marine environment,*
> d. *provide assurances that evacuated areas can be re-occupied,*

e. provide assurances that normal activities may be resumed in affected areas

OPSMAN1, Section 32. *Substantial resources of staff and equipment may be needed for this purpose but the requirement is less urgent than that of the immediate post-accident monitoring. Therefore, these resources can be obtained from other centers, including those remote from the port being visited. Organizations which are expected to contribute this assistance are to be informed beforehand.*

2.2 Reference Accident

Much of the planning for managing potential radiation exposures is based on the modelling results of the *Reference Accident* [6]. The *Reference Accident* is computer model devised for estimating the nature and extent of the radioactive contamination for a severe accident scenario involving a loss of coolant accident in a NPW reactor and the subsequent release of radioactive material to the environment. The *Reference Accident* is used to assess the acceptability of a port for visits by NPWs and to establish the planning zones for the initial radiation emergency response.

The *Reference Accident* predicts that, after the passage of the radioactive cloud, the two principal pathways for exposure would be through external irradiation and from ingestion of radioactivity. Resuspension of surface contamination and the subsequent inhalation would be very small. The *Reference Accident* predicts that the major component of the release would be radioiodine, with the initial levels of Cs-137 contamination predicted to be at least an order of magnitude lower than the initial radioiodine levels. However, Cs-137 has a much longer half-life than radioiodine and the Cs-137 contamination is more persistent. Both Cs-137 and radioiodine contamination can move easily into the environment, and this implies that all foodstuff produced in the affected area, particularly milk would need to be monitored closely to ensure that the radiation dose to critical members of the public is minimized.

3 Guidelines for Protective Measures

An accident involving the reactor of an NPW can result in the release of volatile radionuclides, ^{131}Te, ^{134}Cs, ^{137}Cs, ^{103}Ru, ^{106}Ru ^{131}I, ^{132}I, ^{133}I and noble gases. It is the definition and management of this radioactive contamination that forms the basis for the long-term response to the NPW accident (post-accident recovery phase).

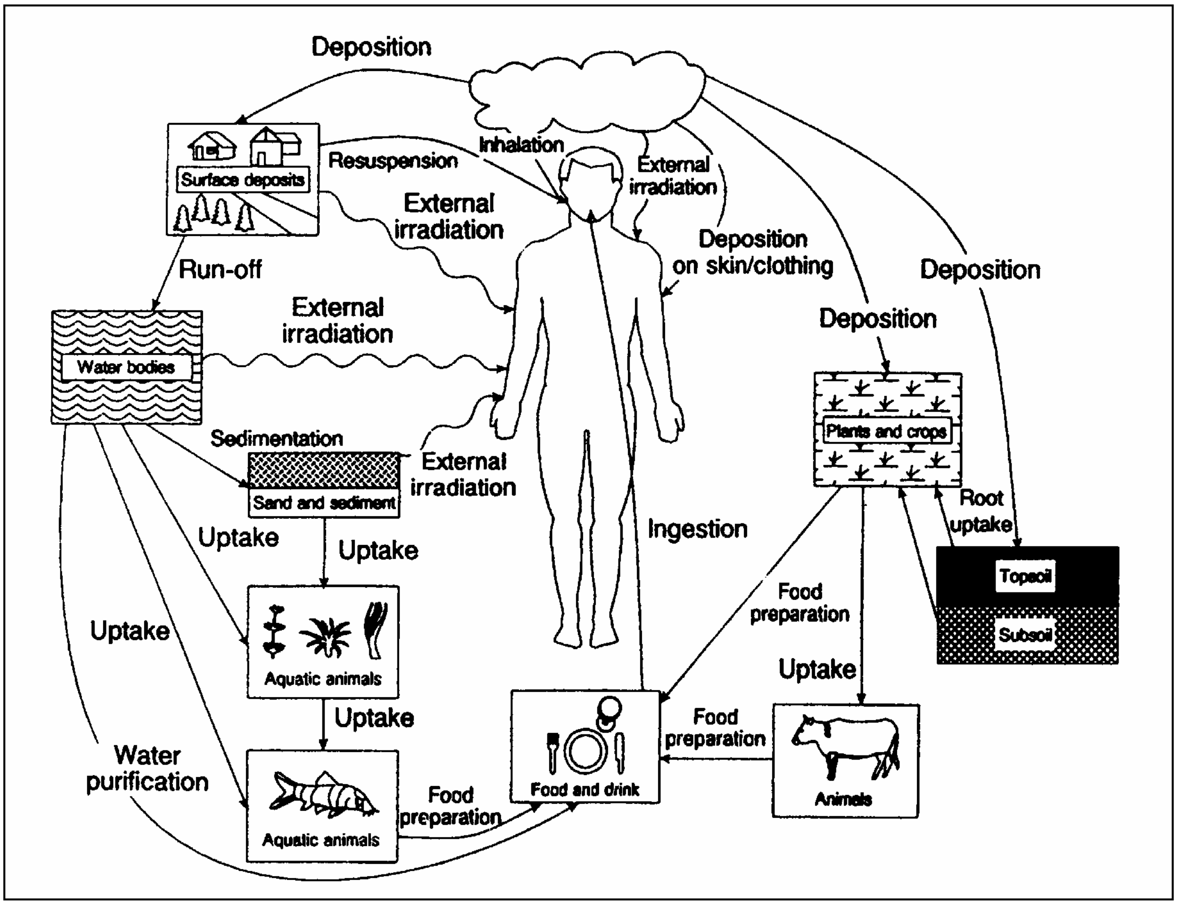
3.1 Exposure Pathways

For a reactor accident involving a release of radioactive material, the main pathways for exposure to members of the public are shown schematically in Figure 1. These include:

(a) Direct external radiation from the radioactive cloud or plume
(b) Direct external exposure from radioactivity deposited on the ground
(c) Internal exposure from inhalation of particles or volatile radionuclides
(d) Internal exposure from ingestion of contaminated material

Once released, the radioactivity is transported and dispersed by atmospheric processes. The initial exposure pathway of concern for exposure to members of the public is through the inhalation of the radioactivity in this cloud, principally I-131, with the subsequent radiation dose to the thyroid. As the radioactive cloud moves forward, radioactivity is deposited onto the ground under the cloud, leading to contamination of soil, buildings, plants and water. Both Cs-137 and I-131 contamination can move easily into the environment. In the short term (weeks) I-131 is the principal concern, through uptake into the thyroid and the subsequent increase risk of thyroid cancer. Cs-137 is more persistent and provides principal source of the long-term contamination.

Figure 1 Human Exposure Pathways
(Adapted From IAEA Safety Series 109 [(7)])



3.2 Implementation of Protective Measures

In Australia the recommended approach for radiation protection in these circumstances is described in ARPANSA Radiation Protection Series No 7 *Intervention in Emergency Situations Involving Radiation Exposure* [(8)]. These Recommendations are based on the general principals provided in the IAEA Basic Safety Standard 115 (BSS115)[(9)] and developed in more detail in the IAEA Safety Series 109[(7)]. The decision on the use of a particular intervention should be based on three general principles:

1. Serious deterministic health effects should be avoided
2. The intervention should be justified (that is do more good than harm)
3. The intervention should be optimised (that is provide maximum net benefit)

Radiation emergency protective actions include:

a. **urgent protective actions**, which must be taken within hours of an accident to be effective. These include: sheltering, evacuation, and intake of stable iodine tablets.

- Sheltering. Sheltering involves keeping members of the population indoors, in suitable buildings, to reduce radiation exposure from airborne radioactive material and from 'ground shine'. Sheltering is not recommended for a period exceeding 48 hours. This period may be significantly less depending upon climatic conditions.

  During the early stages of the release, while a radioactive plume of mixed radionuclides is passing, a large proportion of the individual dose may arise from inhalation. Sheltering in a building can reduce the dose from inhalation by a factor of 2 and external doses from the passing plume can be reduced by up to an order of magnitude within brick or large buildings. The efficacy of this countermeasure reduces over time. The use of lightweight or open buildings provides less protection.
- Evacuation. Evacuation is the urgent removal of the population from the affected area. It is generally the most effective protective action against major airborne releases of radioactive material. Evacuation and accommodation in emergency facilities is not recommended for a period exceeding 7 days.
- Administration of stable iodine tablets. Inhaled radioactive iodine tends to concentrate in the thyroid gland and can cause early or latent effects such as thyroid cancer. Ingesting stable, non radioactive iodine, before or immediately after exposure to a release of radioactive iodine saturates the thyroid gland and prevents the absorption of radioactive iodine in the body.

  For maximum reduction in radiation dose to the thyroid stable iodine should be administered before any uptake of radioactive iodine otherwise as soon as practicable thereafter. Stable iodine administered up to 6 hours prior to exposure to radioactive iodine can provide almost complete protection. Stable iodine administered at the time of exposure to radioactive iodine can avert about 90% of the dose. The effectiveness of the countermeasure decreases with delay in administration.

b. **longer-term protective actions**, which may need to be adopted in a matter of days following an accident to reduce the risk of health effects from ingestion of contaminated foodstuffs, either locally grown or sold in the affected area should be developed in advance. These include: analysis and control of foodstuff, relocation and resettlement. In general, protective actions such as relocation, food restrictions and agricultural countermeasures will be based on environmental monitoring and food sampling.

To assist in the planning for implementing protective actions a series of pre-planned intervention and action levels are defined:
Intervention levels are the level of **avertable** dose at which a **specific** protective action or remedial action is taken in an emergency exposure situation or chronic exposure situation.

Action levels are the level of **dose rate or activity concentration** above which remedial actions or protective actions (non-specific) should be carried out in chronic exposure or emergency exposure situations.

Protective actions should be carried out on the basis of intervention levels and action levels. The procedures for the determination of appropriate values of intervention and/or action level are based on the balancing the risks associated with the implementing the countermeasure, against the risks reduction associated with the averted radiation dose. For planning purposes, the optimisation process is carried out for representative populations exposed to conditions expected following a range of radiation accident scenarios, to give a set of generic optimised levels. The derived *generic intervention levels* (GIL) apply to urgent and longer-term protective actions for the public and *generic action levels* (GAL) apply to controls on food.

International and national guidance specifies:

- Generic Intervention Levels (GIL) at which urgent and longer term protective actions should be taken by the public. Intervention levels are expressed in terms of the dose that is expected to be averted over time by a specific protective action associated with the intervention. Recommended values are given in Table 1.
- Generic Action Levels (GAL) at which control should be placed on foodstuffs, water and crops. Recommended values are given in Table 2.

The decision to use a particular protective measure should be based on an estimate of the dose to be averted by carryout the protective action, relative to the appropriate Generic Intervention Level or Generic Action Levels .

3.3 Operational Intervention Levels

GILs and GALs were not designed to be used during an emergency; they cannot be promptly measured in the field and do not address conditions specific to the accident. However, as part of planning, they should be used to develop ***Operational Intervention Levels* (OILs)**. These OILs are based on quantities that can be determined and/or measured during an emergency e.g., ambient dose rate in plume or from deposition, marker radionuclide concentration in deposition or foodstuff and on which the need for protective action can be rapidly ascertained. There are OILs for each protective action. They are based on the generic intervention levels, combined with assumptions about the source term isotopic composition, the duration of the release, and the decay profile of ground and food contamination.

Table 1. Recommended Generic Intervention Levels for Protective Measures for the General Public[8]

Protective action	Generic intervention level
Urgent protective measures	
Evacuation	50 mSv
Sheltering	10 mSv
Iodine prophylaxis	100 mGy Adult thyroid dose
	30 mGy Child thyroid dose
Longer Term Protective Measures	
Temporary relocation and permanent resettlement	30 mSv in first month
Temporary relocation	10 mSv in a subsequent month
Permanent relocation	1 Sv in lifetime

Table 2. Generic Action Levels for Food [8]

Foods destined for general consumption		
Isotope group	**Radionuclides**	**Generic action levels GAL[a] [kBq/kg]**
1	Cs-134, Cs-137, Ru-103, Ru-106, Sr-89, I-131	1
2	Sr-90	0.1
3[b]	Am-241, Pu-238, Pu-239, Pu-240, Pu-242	0.01
Milk, infant food, and water		
4	Cs-134, Cs-137, Ru-103, Ru-106, Sr-89	1
5	Sr-90, I-131	0.1
6[b]	Am-241, Pu-238, Pu-239, Pu-240, Pu-242	0.001

(a) *The GAL apply to the sum of the activity of the isotopes in each group independently.*

(b) *The Pu and Am isotopes should not be important sources of ingestion dose for reactor accidents and their groups need not be considered for NPW reactor accidents.*

3.3.1 OILs for Protective Measures in Urgent Phase

OILs from Ambient Dose Rate in Plume [mSv/h]

- OIL1 is the operational intervention level for evacuation, expressed as the ambient dose rate in the plume. The default value for OIL1 in a reactor accident involving a breach of the containment vessels is **1 mSv/h**. OIL1 should never be higher then 10 mSv/h. The default value is calculated for an unsheltered person in the plume taking into account the mixture of fission products for a core melt accident.

- OIL2 is the operational intervention level for thyroid blocking and sheltering, expressed as the ambient dose rate in the plume for an unsheltered adult. The default value for OIL2 for a core damage accident is a thyroid dose of **0.1 mSv/h (100 µSv/h).**

- OIL2b is the operational intervention level for thyroid blocking and sheltering, expressed as the ambient dose rate in the plume for an unsheltered child. The default value for OIL2 for a core damage accident is a thyroid dose of **0.02 mSv/h (20 µSv/h).**

OILs From Ambient Dose Rate From Deposition [mSv/h]

- OIL3 is an operational intervention level for evacuation or substantial sheltering. The default value for OIL3 for a core damage accident is **1 mSv/h** .

In Table 3 lists the Operational Intervention Levels for the urgent phase of a reactor accident.

Table 3. Recommended Operational Intervention Levels for Urgent Phase(8)

Basis	OIL	Default Value	Protective Action
Ambient dose rate in plume	**OIL1**	1 mSv/h[(a)]	Evacuation
	OIL2	100 µSv/h[(b)]	Iodine Prophylaxis or Sheltering (Adult)
	OIL2b	20 µSv/h[(b)]	Iodine Prophylaxis or Sheltering (Child)
Ambient dose rate from deposition	**OIL3**	1 mSv/h	Evacuation or Substantial Shelter

(a) If there is no indication of core damage, OIL1 = 10 mSv/h.
(b) Air samples should collected and analysed to confirm the release of radioiodine.

3.3.2 OILS for Longer Term Protective Measures

Ambient Dose Rate From Deposition OILs [mSv/h]

- OIL4 is an operational intervention level for temporary relocation. The default value for OIL4 for a core damage accident is **0.2 mSv/h (200 μSv/h).**

- OIL5 is an operational intervention level for precautionary restriction of food and milk. The default value for OIL5 for a core damage accident is **1 μSv/h).**

These two OILs are all expressed in terms of the ambient dose rate from deposition.

For a NPW reactor accident, the dominant radionuclides that can be easily measured and assessed are I-131 and Cs-137. These isotopes can act as tracer isotopes, i.e. other less significant radionuclides can be assumed to be in a fixed ratio to these marker isotopes, and protective actions indicated by reference to the measurement of the marker isotopes alone. When detailed isotopic information becomes available, procedures are needed to check that these assumptions remain valid.

Marker Radionuclide Ground Deposition Concentration OIL [kBq/m^2]

- OIL6 is an operational intervention level above which restrictions for food and milk are recommended. It is expressed in terms of the I-131 (marker radionuclide) ground deposition concentration. OIL7 has the same function as OIL6 except that the marker radionuclide is Cs-137.
- OIL7is an operational intervention level above which restrictions for food and milk are recommended. OIL7 has the same function as OIL6 except that the marker radionuclide is Cs-137. It is expressed in terms of the Cs-137 (marker radionuclide) ground deposition concentration.

Marker Radionuclide Concentration in Food, Milk, Water OILs [kBq/kg]

- OIL8 is an operational intervention level above which restrictions for food and milk or water are recommended. It is based on I-131 (marker radionuclide) activity concentration but measured in food and milk or water, rather than ground deposition.
- Similarly, OIL9 is an operational intervention level above which restrictions for food and milk or water are recommended, except that the marker radionuclide is Cs-137.

Table 4 summarises the Operational Intervention Levels for the longer term protective measures following a reactor accident. Table A2 in ANNEX A summarises the assumptions under which default values in Table 3 and 4 were calculated. The default values of OILs included in emergency plans are meant to be used as initial criteria for indicating the need for protective actions. As more information becomes available during an accident, the assumptions need to be reviewed and the OILs re-assessed. Only if there are major differences between the default and recalculated values should the OILs be revised.

Table 4. Recommended Operational Intervention Levels Longer Term Protective Measures[8]

Marker radionuclide concentrations in ground deposition			
Basis	**OIL**	**Default Value**	**Protective Action**
Ambient dose rate from deposition	**OIL4**	200 µSv/h	Temporary Relocation
	OIL5	1 µSv/h	Restriction of Food

Marker radionuclide concentrations in ground deposition				
Basis	**OIL**	**Default Value**		**Protective Action**
Ground Contamination		**General food**	**Milk**	
I-131	**OIL6**	10 kBq/m^2	2 kBq/m^2	Restriction of Food
Cs-137	**OIL7**	2 kBq/m^2	10 kBq/m^2	Restriction of Food

Marker radionuclide concentrations in food, milk, water				
Basis	**OIL**	**Default Value**		**Protective Action**
Contamination of Foodstuff		**General food**	**Milk and water**	
I-131	**OIL8**	1 kBq/kg	0.1 kBq/kg	Restriction of Food
Cs-137	**OIL9**	0.2 kBq/kg	0.3 kBq/kg	Restriction of Food

3.4 Revision of OILS

The default values of OILs included in emergency plans are meant to be used as initial criteria for indicating the need for protective actions. This approach is illustrated in Figure 2. As more information becomes available during an accident, the assumptions need to be reviewed and the OILs re-assessed. Only if there are major differences between the default and recalculated values should the OILs be revised. The procedures for the revision of OILs are given in ANNEX A and listed in Table 5. These procedures are taken from RPS7 (8) published in 2004, and are based on the methodologies in IAEA TECDOC 955 (4).

Figure 2 Use and Revision of OILs for Protective Measures

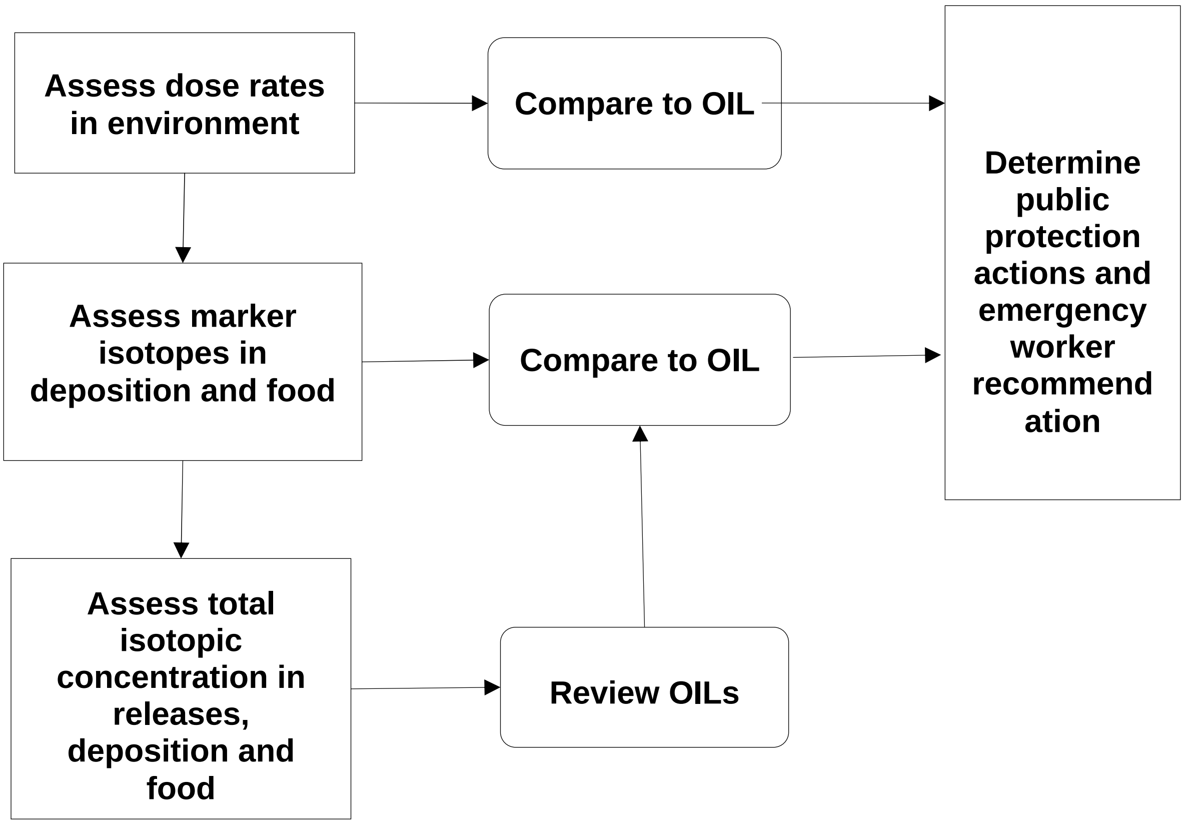


Table 5 Summary of Methods for Revision of OILs from Annex A

	PROCEDURE
A1	Revision of Plume Exposure Evacuation Oil
A2	Revision of Plume Exposure Shelter Oil
A3	Revision of Emergency Turn Back Guidance
A4	Revision of Deposition Exposure Relocation Oil
A5	Revision of I-131 Deposition Concentration Oil For Ingestion
A6	Revision of Cs-137 Deposition Concentration Oil For Ingestion
A7	Evaluation of Food Restrictions and Revision of I-131 Food Oils
A8	Evaluation of Food Restrictions and Revision of Cs-137 Food Oils
A9	Calculation of Isotope Concentrations in Food

4.0 Environmental Monitoring

The design of an emergency monitoring and sampling program is determined by nature of the radiation release and the available expertise and resources to respond. The objective of an emergency monitoring and sampling program is to determine whether, when or where to apply protective actions. During and immediately after a NPW radiological accident it is essential to ensure that those resources are utilised as effectively and efficiently as possible. The approach taken in this Handbook is based on the generic procedures outlined in IAEA TECDOC 955[4] and TECDOC 1092 [5], adapted to Australian operational requirements and resources.

4.1 Monitoring Priorities

Currently *OPSMAN1*[1] requires removal of vessel within 12 hours or less. This removes the source term but not the radioactive contamination from the passage of any radioactive cloud. For an accident involving atmospheric release, several monitoring teams will be required to determine hazard to population by defining the extent of the plume, air concentrations in the plume and deposition from the plume. Monitoring teams will need to make ambient dose rate measurements of cloud shine, ground shine or directly from the source.

At the outset, all available meteorological information and model predictions should be used to determine the geographical area where people can be affected by the release of radioactive material. The priority for monitoring and sampling should then take into account the composition of that area, i.e., whether it is residential, agricultural, rural, commercial, and whether it features industrial activities, public services and infrastructure elements. The need for additional protective actions for people, livestock, crops, water supplies, etc., embargoes on the use of water and food, and the maintenance or restoration of vital infrastructure elements should then be based on operational intervention levels and other factors. The priorities for environmental monitoring are summarized in Table 6.

4.1 .1 Immediate Post Accident Phase (hours)

In the early phase of an accident involving airborne contamination the sampling priority is the in-plume air sampling during the release; measurement of radionuclide concentration provides necessary data for evaluation of inhalation hazards and for recalculation of OIL1, OIL2 and OIL2b. Monitoring teams need to be deployed immediately the alarm has been confirmed in order to ensure the maximum protection of members of the public, with due consideration for the safety of the monitoring teams. In the initial response, the determination of which affected areas are truly “dirty” should take precedence over quantitative analysis, particularly when response resources are limited.

For this immediate phase the Radiation Monitoring Groups (RMG) are responsible for carrying out initial measurements and report the results back to the Radiation Controller in the form of monitoring reports (MONREPS) [2]. The procedures and tasks for the RMG are given in the *Radiation Monitoring Handbook for Visits by Nuclear Powered Warships to Australian Ports*[2]. The RMG are made up of on-call State experts and Defence Personnel working with an ANSTO Leader RMG. Information from the first MONREPS should be available within the first hour.

Table 6 Environmental Monitoring Priorities

Priority	When	Where	Team	Objective	Results
1	After declaration of Alert and thereafter once an hour	Areas close to the NPW in all directions [(a)]	Radiation Monitoring Group (RMG)	To detect major releases from the NPW and locate plume direction	Record on MONREP worksheet and provide results to Leader RMG
2	During and after a release	Areas not evacuated - begin in populated areas (e.g., towns) where projections indicate evacuation is warranted but ensure that all directions are monitored.	Radiation Monitoring Group (RMG)	To identify where ambient dose rates indicate urgent protective actions are warranted (OIL1, OIL2 and OIL3 are exceeded)	Record on MONREP worksheet and provide to Leader RMG
3	During a release [(b)]	In plume	Radiation Monitoring Group (RMG)	To take and analyse air samples and ambient dose rates to recalculate OIL1 and OIL2	Record on MONREP worksheet and provide to Leader RMG
4	After a release has ended or after plume passage [(c)]	Areas not evacuated, start with area where highest dose rates were seen during release	Environmental Survey Team (EST)	To identify where ambient dose rates from deposition indicate that relocation is warranted (OIL4 exceeded) or indicate that food should be restricted until sampled (OIL5 exceeded)	Record on Worksheets and provide to Analysis and Assessment Team (AAT)
5	After a release has ended or after plume passage [(c)]	Areas not evacuated and beyond those where the relocation OIL4 has been exceeded.	Radiation Analysis Team (RAT)	Identify where I-131 or Cs-137 deposition concentration indicate food should be restricted until sampled (exceeds OIL6 and OIL7)	Record on Worksheets and provide to Analysis and Assessment Team (AAT)

6	After a release has ended or after plume passage [c]	Representative points in all directions of contaminated area. [d]	Environmental Survey Team	To take and analyse deposition samples or use gamma *in-situ* spectroscopy to recalculate the OIL4, OIL6 and OIL7	Record on Worksheet and provide to Analysis and Assessment Team (AAT)
7	After a release has ended or after plume passage [c]	Start where OIL6 and OIL7 were exceeded, but ensure that all areas where deposition could result in food restrictions should be evaluated	Environmental Survey Team	To take and analyse food, water and milk samples to identify if OIL8 and OIL9 in food are exceeded and restriction on ingestion are warranted [e]	Record on Worksheet and provide to Analysis and Assessment Team (AAT)

(a) Conduct monitoring in all directions around the vessel and record sector, distance from the NPW, time and highest dose on the MONREP Worksheet. Monitoring results should be obtained within 1 - 2 km zone around the NPW.

(b) Perform only if: 1) the release is expected to last 4 hours or more and 2) the plume can be measured at ground level.

(c) E.g., after a wind shift while the release is still going on.

(d) The deposition pattern may be very complex and the mixture of fission products may vary by location and time (e.g., decay and ingrowth). Therefore sufficient samples must be taken to ensure the deposition pattern and mixture are understood.

(e) Take food and milk samples in areas where ambient dose rates and depositions concentrations indicate restrictions may be needed. Take samples of each major food type in accordance with the agricultural sampling plan (developed as part of the planning process).

4.1.2 Longer-Term Response (days – weeks – months)

Having determined the immediate situation and taken appropriate urgent actions, sampling programmes need to be established to determine whether persons need to be temporarily relocated and animals need to be sheltered and provided with uncontaminated food. Vegetables and other locally grown produce, drinking water supplies and milk from local dairies need to be checked for comparison with action levels. The extent and nature of such sampling programs will depend on the extent and scale of the release and the demographics of the location in terms of agricultural practices and population distribution.

The sampling priorities are;

(a) soil sampling after end of the release or after plume passage; measurement of radionuclide concentrations gives values for ground deposition and necessary data to recalculate OIL4, OIL6 and OIL7;

(b) *sampling of contaminated food, water and milk* after end of the release or after plume passage; measurement of radionuclide concentrations provides input data for food restrictions.

4.2 Radiation Emergency Teams

The post accident recovery phase uses a series of monitoring teams with expertise and resources to address particular radiological pathways.

- The *Environmental Survey Team* is made up of ARPANSA technical personnel trained in radiation dose rate and surface contamination measurements and in the use of GPS-based techniques for mapping the nature and extent of the contamination. In addition, the Environmental Survey Team should be trained at taking air samples, and in the collection of field samples of water, soil, foodstuff and other material as required. Team members need to be skilled in the use of contamination monitors to assess personal contamination of skin and clothing and of contaminated objects, surfaces, equipment and vehicles, to prevent the spread of contamination and to monitor the efficiency of decontamination of people and surfaces.

- *The Radiation Analysis Team (RAT)* is a specialist team, skilled in the use of radiation measurement system to identify and quantify specific radionuclides in field situations. The Radiation Analysis Team should be able to determine radionuclide specific ground contamination, to perform sampling and initial sample preparation, and to measure radionuclide concentration in samples (air, soil, water, foodstuffs, etc.). The RAT would support the detailed analysis of the radionuclide composition of ground contamination, and the detailed analysis of radionuclide compositions and concentrations in various environmental samples, which can then be compared to OILs and generic action levels (GALs).

- The *Analysis and Assessment Team* consists of personal trained in the analysis of radiation monitoring data from the ground-based measurement systems and in the production and interpretation of maps dealing with radioactive contamination. The leader of the AAT is a professional operational or environmental health physicist knowledgeable and experienced in environmental and source monitoring techniques and knowledgeable in the use of OILs. This team would be initially based at ARPANSA Melbourne but in the later stages of the incident response the team may work from the Emergency Coordination Center or a mobile laboratory as appropriate. It is the responsibility of the Team to process the field data into a suitable form for interpretation by the Commonwealth Technical Advisor (CTA) and the State Radiation Control Officer. The AAT will coordinate with CTA, the field teams, the Leader of the Radiation Monitoring Group and State Radiation Controller to ensure the relevant data is collected.

- The *Commonwealth Technical Advisor* (normally a senior ARPANSA radiation expert) is responsible for the coordination of the ARPANSA teams. In the event of a NPW radiation accident the State Emergency Services for the affected State may request additional Commonwealth assistance through contact with EMA. Commonwealth resources such as Defence, ARPANSA and ANSTO would be sent. Except for an NPW accident in Melbourne, transporting the initial resources units to the affected location would take from 4 to 24 hours. If an accident or emergency is likely to continue over an extended period of time, arrangements should be made for replacement emergency monitoring and sampling teams to substitute those in the field.

4. 3 Laboratory Analysis

The *Laboratory Analysis Teams* are composed of persons well trained in sample preparation gamma spectrometry and other radionuclide analysis techniques. Such persons should be routinely engaged in such analyses, employing well-calibrated equipment and utilizing recognized and validated analytical techniques. Such persons may be drawn from universities, government analytical laboratories such as those at ARPANSA and ANSTO, research laboratories, or industrial laboratories. It is important for emergency planners to be aware of what resources in terms of staff and equipment are available from such organizations. As part of preparedness, examples of the types of samples that may require assessment should be provided and such persons should be exercised in responding to an accident in which large numbers of samples may need to be rapidly analyzed and results promptly reported.

4.4 Commonwealth-State Coordination

The operational arrangements will vary from State to State. In particular, the arrangements between the State emergency services, police, ambulance and fire services will vary.. All NPW Port Plans specify a Counter Disaster Controller and a State Radiation Officer who operate from the Emergency Operations Centre. Emergency Management Australia (EMA) coordinates the Australian Government response, and;

- The Counter Disaster Controller is the person who will be in overall charge of an emergency and carry the ultimate responsibility for the emergency response. This might be a senior police officer, or a local or senior government official. This position is most unlikely to be taken on by a radiological professional since radiation matters are likely to be only a single contributory factor in the overall response to an accident.

- The State Radiation Officer is normally a professional health physicist responsible for determining protective actions based on accident classification and environmental monitoring and is responsible for advising the NPW Port Safety Organisation.

When the members of the monitoring teams are drawn from Commonwealth and International organizations, the Commonwealth Technical Advisor is responsible for the directing the activities of the field teams. Each Commonwealth organization has responsibilities under the COMDISPLAN(10) and requests for assistance from the State organizations should be directed through EMA.

5 REFERENCES

[1] Department of Defence Operations Manual (OPSMAN1), *Visits to Australian Ports by Nuclear Powered Warships*, Edition 5, Visiting Ships Panel (Nuclear), Canberra, (2000).

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[7] International Atomic Energy Agency, Intervention *Criteria in a Nuclear or Radiation Emergency*, Safety Series No. 109, IAEA, Vienna (1994).

[8] Australian Radiation Protection and Nuclear Safety Agency, Protection Series No 7, *Intervention in Emergency Situations Involving Radiation Exposure, ARPANSA*, Melbourne, (2004).

[9] International Atomic Energy Agency, *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*, Safety Series No. 115, IAEA, Vienna (1996).

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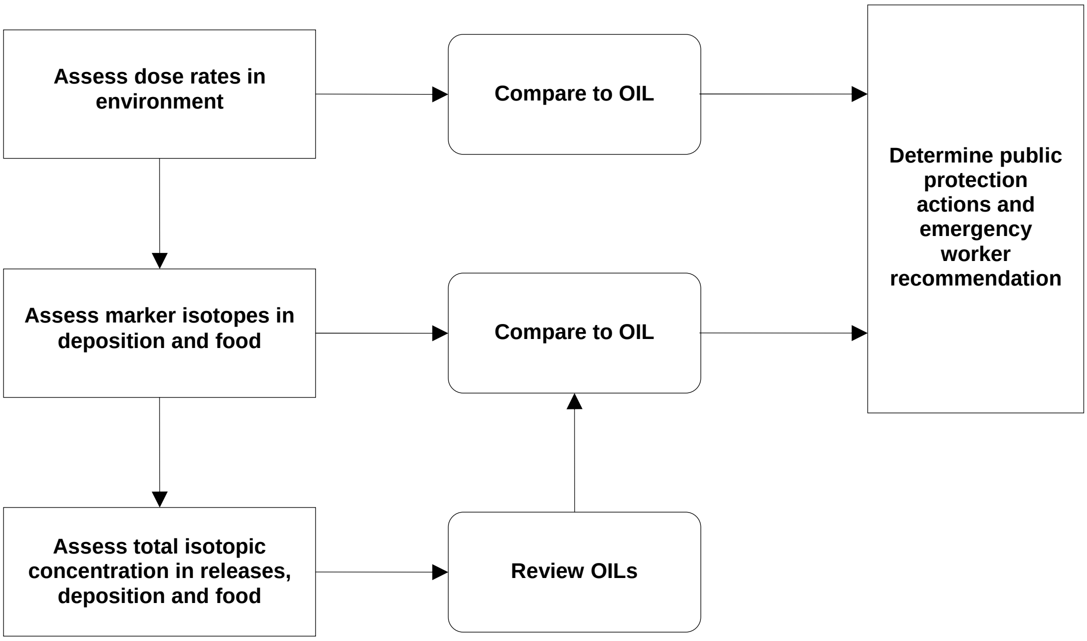
Annex A

Revision of Operational Intervention Levels (OIL)

Environmental data are assessed primarily through the use of Operational Intervention Levels (OIL), which are quantities directly measured by the field instruments. Table A1 lists the default OILs calculated on the basis of the characteristics of a significant reactor accident, under the assumptions summarised in Table A2. (RPS7 2004, IAEA 1997). These default OILs are used to assess environmental data and take protective actions until sufficient environmental samples are taken and analysed to provide a basis for their revision. This approach allows data to be quickly evaluated, and decisions on protective actions to be promptly made. This approach is illustrated in Figure A1..

Figure A1



As more information becomes available during an accident, the assumptions need to be reviewed and the OILs re-assessed The procedures for the revision of OILs in this ANNEX, listed in below, are taken from RPS7 2004 and are based on the methodologies in IAEA TECDOC 955 (IAEA 1997). Only if there are major differences between the default and recalculated values should the OILs be revised.

Method A1 *Revision of Plume Exposure Evacuation OIL*
Method A2 *Revision of Plume Exposure Shelter OIL*
Method A3 *Revision of Emergency Turn Back Guidance*
Method A4 *Revision of Deposition Exposure Relocation OIL*
Method A5 *Revision of I-131 Deposition Concentration OIL for Ingestion*
Method A6 *Revision of Cs-137 Deposition Concentration OIL for Ingestion*
Method A7 *Evaluation of Food Restrictions and Revision of I-131 Food OILs*
Method A8 *Evaluation of Food Restrictions and Revision of Cs-137 Food OILs*
Method A9 *Calculation of Isotope Concentrations in Food*

Table A1: Recommended Operational Intervention Levels for Reactor-Based Accidents

Basis	OIL	Default Value		Protective Action
Ambient dose rate in plume	OIL1	1 mSv/h [(a)]		Evacuation
	OIL2	100 µSv/h		Sheltering
	OIL2	100 µSv/h[(b)]		Iodine Prophylaxis Adult
	OIL2c	20 µSv/h[(b)]		Iodine Prophylaxis Child
Ambient dose rate from deposition	OIL3	1 mSv/h		Evacuation or Substantial Shelter
	OIL4	200 µSv/h		Temporary Relocation
	OIL5	1 µSv/h		Restriction of Food
Marker radionuclide concentrations in ground deposition		General food	Milk	
I-131	OIL6	10 kBq/m^2	2 kBq/m^2	Restriction of Food
Cs-137	OIL7	2 kBq/m^2	10 kBq/m^2	Restriction of Food
Marker radionuclide concentrations in food, milk, water		General food	Milk and water	
I-131	OIL8	1 kBq/kg	0.1 kBq/kg	Restriction of Food
Cs-137	OIL9	0.2 kBq/kg	0.3 kBq/kg	Restriction of Food

(a) If there is no indication of core damage, OIL1 = 10 mSv/h.

(b) Air samples should be collected and analysed to confirm the release of radioiodine.

Table A2: Assumptions Used For Default Reactor-Based OILs

OIL	Summary of assumptions For calculating default values
OIL1	Calculated assuming an unreduced release from a core melt accident resulting in an inhalation dose 10 times the dose from external exposure, 4 hour exposure to the plume, and 50 mSv can be averted by the action. If there is no indication for core damage, OIL1 = 10 mSv/h.
OIL2	Calculated assuming an unreduced release from a core melt accident resulting in a thyroid dose from inhalation of iodine 200 times the dose from external exposure, 4 hour exposure to the plume, and 100 mGy can be averted by the action.
OIL2b	Calculated assuming an unreduced release from a core melt accident resulting in a thyroid dose from inhalation of iodine 200 times the dose from external exposure, 4 hour exposure to the plume, and 30 mGy can be averted by the action.
OIL3	Calculated to avert 50 mSv by the action, 1-week exposure period and approximately a 75% reduction in dose due to decay, sheltering and partial occupancy.
OIL4	Calculated to avert 30 mSv by the action in 30 days, ground contamination of a typical core melt mixture of radionuclides 4 days after accident and 50% reduction in dose due to partial occupancy, decay and weathering. Should be valid for 2-7 days after shutdown.
OIL5	Assumes that the food or milk produced in an area with above background dose rates from deposition may be contaminated beyond the GALs. This is true for most core melt accidents and directly contaminated food before processing and milk from cow grazing on contaminated grass.
OIL6	Calculated assuming: a) I-131 will be controlling which should be valid for fresh fission product mixes (within 1-2 months of shutdown), b) food is directly contaminated or the cows are grazing on contaminated grass, c) food is consumed immediately without processing to reduced contamination.
OIL7	Calculated assuming: a) Cs-137 will be controlling which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown), b) food is directly contaminated or the cows are grazing on contaminated grass, c) food is consumed without processing to remove contamination (for goat milk multiply OIL6 and OIL7 with 0.10).
OIL8	Calculated assuming: a) I-131 will be controlling which should be valid for fresh fission product mixes (within 1-2 months of shutdown), b) food is consumed immediately without processing to remove contamination.
OIL9	Calculated assuming: a) Cs-137 will be controlling which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown), b) food is directly contaminated and consumed immediately without processing to reduce contamination.

OIL1: Evacuate based on ambient dose rate in plume.

- Person is exposed for 4 hours, by which time a major wind shift would be expected.
- Unsheltered person in the plume.
- Mixture of fission products for a core melt as defined in IAEA 1997.
- Reduction in dose due to partial occupancy in normal home has small impact compared to great uncertainties in dose and dose measurement during a release and therefore need not be considered.
- Calculated using method shown in Procedure A1 with:
  - T_e (exposure duration) = 4h
  - R_1 = 10 (ratio of total effective dose rate to ambient dose rate) based on computer modelling (IAEA 1997).
  - GIL_1 (Generic Intervention Level) for evacuation 50 mSv averted in one week.

$$OIL1 = \frac{50\ m\ Sv}{4\ h} \times \frac{1}{10} = 1.25\ m\ Sv/h \approx 1\ m\ Sv/h$$

OIL2 Iodine Prophylaxis based on ambient dose rates in the plume.

- Person is exposed for 4 hours, by which time a wind shift would be expected.
- Unsheltered person in the plume.
- Release of the fission products in the gap or from core melt as defined in IAEA 1997.
- Calculated using method shown in Procedure A1 with:
  - T_e (exposure duration) = 4h
  - R_2 = 200 (ratio of thyroid dose rate to ambient dose rate) for a core melt unreduced release based on computer modelling (IAEA 1997).
  - GIL_2 (Generic Intervention Level for iodine prophylaxis) organ dose of 100 mSv can be averted.

$$OIL2 = \frac{100\ mSv}{4\ h} \times \frac{1}{200} = 0.125\ mSv/h \approx 0.1\ mSv/h$$

OIL2C: Iodine prophylaxis based on ambient dose rates in the plume.

- Child is exposed for 4 hours, by which time a wind shift would be expected.
- Unsheltered 10 year old child in the plume.
- Release of the fission products in the gap or from core melt as defined in IAEA 1997.
- Calculated using method shown in Procedure A1 with:
  - T_e (exposure duration) = 4h
  - R_2 = 350 (ratio of thyroid dose rate to ambient dose rate) calculated from adult ratio of thyroid to ambient dose rate, adjusted on the basis of the ratio of adult to child inhalation dose conversion factors for I-131 in Table A3 below (200 × 0.41 / 0.23 ~ 350).
  - GIL_2 (Generic Intervention Level for iodine prophylaxis for children) organ dose of 30 mSv can be averted.

$$OIL2 = \frac{30\ mSv}{4\ h} \times \frac{1}{350} = 0.0214\ mSv/h \approx 0.020\ mSv/h$$

Table A3 Adult to Child Inhalation Dose Conversion Factors for I131

Committed Equivalent Dose to the Thyroid from One-Hour's Inhalation of Contaminated Air

Radionuclide	Conversion factor [(mSv/h)/(kBq/m^3)]	
	Adult	10 years
Te-131m	2.0×10^{-2}	3.7×10^{-2}
Te-132	3.8×10^{-2}	6.8×10^{-2}
I-125	1.5×10^{-1}	2.5×10^{-1}
I-129	1.1	1.5
I-131	2.3×10^{-1}	4.1×10^{-1}
I-132	2.1×10^{-3}	3.8×10^{-3}
I-133	4.2×10^{-2}	8.3×10^{-2}
I-134	3.9×10^{-4}	7.3×10^{-4}
I-135	8.6×10^{-3}	1.7×10^{-2}

Note: A breathing rate of 1.5 m^3/h and 1.12 m^3/h was assumed for adult and 10 years old child respectively (as recommended by the ICRP for performing light activity (IAEA 2000).

OIL3: Evacuate based on ambient dose rates from deposition.

- No significant inhalation dose from resuspension (valid for reactor accidents).
- Intervention level for evacuation of 50 mSv 1 week (168 h) exposure period.
- About a 50% reduction in dose due to sheltering and partial occupancy and about 50% reduction in dose due to decay (valid for first few days).

$$OIL3 = \frac{50\ mSv}{168\ h} \times \frac{1}{0.5} \times \frac{1}{0.5} = 1\ mSv/h$$

OIL4: Relocate based on ambient dose rates from deposition.

- Calculated using computer modelling for a mix of fission products from a core melt release four days after shutdown (decay and in-growth are considered) (IAEA 1997).
- GIL_3 (Generic Intervention Level) for relocation of 30 mSv can be averted in a 30 day exposure period.
- About 50% reduction in dose from deposition due to sheltering and partial occupancy.

OIL5: Restrict food based on ambient dose rates from deposition.

- Food is directly contaminated or cows grazed on contaminated grass.
- Deposition containing fission products consistent with core melt inventories and release fractions defined in IAEA 1997.

- Food will be contaminated beyond the Generic Action Levels for restricting consumption anywhere the dose rates from deposition are a fraction of background .
- The operational intervention level should be clearly higher than background (assumed 100 nSv/h), therefore the OIL5 is set to 1 μSv/h.

OIL6 and 7: Restrict food or milk in area indicated based on ground deposition

- Food is directly contaminated or cows are grazing on contaminated grass.
- Calculated using the formula below assuming all the iodine and particulate deposit in the same proportion as released.

Food for general consumption (local produce)

I-131 as marker isotope:

$$OIL6F = \frac{GAL_{G=1} \times Y}{r \times RF} \times \frac{C_{g, I\text{-}131, core\ melt}}{\sum_i^n C_{i, G=1, core\ melt}}$$

Cs-137 as marker isotope:

$$OIL7F = \frac{GAL_{G=1} \times Y}{r \times RF} \times \frac{C_{g, Cs\text{-}137, core\ melt}}{\sum_i^n C_{i, G=1, core\ melt}}$$

Cows Milk

I-131 as marker isotope:

$$OIL6M = \frac{GAL_{G=5} \times Y}{U_{cow} \times r \times f_f} \times \frac{C_{g, I\text{-}131, core\ melt}}{\sum_i^n (C_{i, G=5, core\ melt} \times f_{m,i})}$$

Cs-137 as marker isotope:

$$OIL7M = \frac{GAL_{G=4} \times Y}{U_{cow} \times r \times f_f} \times \frac{C_{g, Cs\text{-}137, core\ melt}}{\sum_i^n (C_{i, G=4, core\ melt} \times f_{m,i})}$$

where:

Y	Productivity; assume 2 kg/m² .
r	Fraction of deposition that is retained on the crop or grass eaten by grazing animals; assume 0.2 (NRC 1977).
RF	Reduction Factor is the fraction of the contamination remaining after decay or some process used to reduce the contamination before food is released for consumption; assume 1.
U_{COW}	Cow consumption; assume 56 kg/day fresh (NRC 1977).
f_f	Fraction of cows diet that is contaminated; assume 1.
$f_{m,i}$	Cow transfer factor for each isotope i from Table A2 [d/L].
OIL6	OIL6F or OIL6M, deposition concentration for isotope I-131 indicating where the total concentration of all the isotopes in a group in local produced food or milk may exceed the GAL.
OIL7	OIL7F or OIL7M, deposition concentration for isotope Cs-137 indicating where the total concentration of all the isotopes in a group in locally produced food or milk may exceed the GAL.
GAL_G	IAEA Generic action level [kBq/kg] for isotope group G (see Table 2).
$C_{g, j, core\ melt}$	Amount of marker isotope j (Cs-137 or I-131) in a release from a core melt accident (IAEA 1997).
$C_{i, G, core\ melt}$	Amount of each isotope in group G from a core melt accident. When calculating OIL7 for Cs-137, it was assumed that the release did not contain any iodine which should be valid for old fission product

mixes (spent fuel or core releases > 2 months after shutdown) (IAEA 1997).

OIL8: I-131 in food, water or milk

- Restrict food or milk of the accident based on food concentration of I-131.
- Food or milk is consumed immediately without washing or other process to reduce contamination.
- The values are only appropriate if food supply are readily available.
- The values were calculated assuming core melt release. OIL8F assumed all the isotopes in group 1 and OIL8M assumed the isotopes in Group 5. In both case the I-131 concentration dominated early in accident so the OIL8 is equal to GAL for the I-131 concentration (IAEA 1997).

OIL9: Cs-137 in food, water or milk

- For the calculation of OIL9F and OIL9M a core melt release mix is assumed without any iodine which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown). The ratio Cs-137 to the total for group 1 (without iodine) is 0.2.
- For Group 4 the mix in the milk was calculated with the transfer factors in Table A4 and the ratio of Cs-137 to the total of Group 4 of 0.3 (IAEA 1997).

Table A4: Cow Transfer Factors

Element	Cow transfer factor f_m [(kBq/L)/(kBq/d)]	Element	Cow transfer factor f_m [(kBq/L)/(kBq/d)]
Hydrogen (H)	1.4×10^{-2}	Antimony (Sb)	2.0×10^{-5}
Manganese (Mn)	8.4×10^{-5}	Tellurium (Te)	2.0×10^{-4}
Cobalt (Co)	2.0×10^{-3}	Iodine (I)	9.9×10^{-3}
Krypton (Kr)	2.0×10^{-2}	Xenon (Xe)	NC
Rubidium (Rb)	1.2×10^{-2}	Caesium (Cs)	7.1×10^{-3}
Strontium (Sr)	1.4×10^{-3}	Barium (Ba)	NC
Yttrium (Y)	2.0×10^{-5}	Lanthanum (La)	NC
Zirconium (Zr)	8.0×10^{-2}	Cerium (Ce)	NC
Niobium (Nb)	2.0×10^{-2}	Praseodymium (Pr)	NC
Molybdenum (Mo)	1.4×10^{-3}	Thorium (Th)	5.0×10^{-6}
Technetium (Tc)	9.9×10^{-3}	Neptunium (Np)	5.0×10^{-6}
Ruthenium (Ru)	6.1×10^{-7}	Plutonium (Pu)	2.7×10^{-9}
Rhodium (Rh)	NC	Americium (Am)	2.0×10^{-5}

NC Not calculated
Reference: IAEA 1997

A1 Revision of Plume Exposure Evacuation OIL

This procedure is used to revise the operational intervention levels used to interpret measurement results in the plume for determining if evacuation (OIL1) is warranted. The procedure should be performed only if there are reliable air samples, accident conditions are stable and a major release is on-going.

STEP 1

To recalculate the OIL1 value from field data, it is necessary to have the air concentrations of the major isotopic contributors to thyroid and effective dose from inhalation (include iodine and caesium) and the average ambient dose rate during the air sampling time ($\overline{\dot{H}^*}$) from field measurements. The thyroid dose and effective dose rate from inhalation of contaminated air are calculated from the summation of the contribution from each radionuclide.

$$\dot{E}_{inh} = \sum_i^n C_{a,i} \times CF_{2,i}$$

where:

$C_{a,i}$	Activity concentration of radionuclide *I* in plume [kBq/m^3] from field measurement.
$CF_{2,i}$	Effective inhalation dose conversion factor for isotope *I* [(mSv/h)/(kBq/m^3)] from Table A3.
$\dot{H}_{thy}$	Dose rate to the thyroid from inhalation [mSv/h].
$\dot{E}_{inh}$	Effective dose rate from inhalation [mSv/h].

STEP 2

Calculate the ratios of the thyroid dose and the total effective dose rate to the external ambient dose rate as specified below:

$$R_1 = \frac{\dot{E}_{inh}}{\overline{\dot{H}^*}} + 1$$

where:

R_1	Ratio of total effective dose rate to ambient dose rate (default assumed 10) [dimensionless].
$\overline{\dot{H}^*}$	Average ambient dose rate from external exposure in the plume where the air sample was taken from field measurements [mSv/h]
$\dot{E}_{inh}$	Effective dose rate from inhalation from Step 1 [mSv/h]

STEP 3

Recalculate OIL1 as specified by the formula below. OIL1 should never be higher than 10 mSv/h.

$$OIL1 = GIL_e \times \frac{1}{R_1} \times \frac{1}{T_e}$$

where:

OIL1	Evacuation operational intervention level [mSv/h].
GIL_e	Generic intervention level for evacuation [mSv], assuming all the dose can be averted by evacuation.
T_e	Exposure duration, assume 4 hours if unknown (typically the wind will shift every four hours) [h].
R_1	Ratio of total effective dose rate to ambient dose rate from step 2 (default assumed 10) [dimensionless].

A2 Revision of Plume Exposure Shelter OIL

This procedure is used to revise the operational intervention levels used to interpret measurement results in the plume for determining if sheltering and thyroid blocking agent (OIL2) is warranted. This procedure should be performed only if there are reliable air samples, accident conditions are stable and a major release is on-going.

STEP 1

To recalculate the OIL2 values from field data, it is necessary to have the air concentrations of the major isotopic contributors to thyroid and effective dose from inhalation (include iodine and caesium) and the average ambient dose rate during the air sampling time ($\overline{\dot{H}^*}$) from field measurements. The thyroid dose and effective dose rate from inhalation of contaminated air are calculated from the summation of the contribution from each radionuclide.

$$\dot{H}_{thy} = \sum_i^n C_{a,i} \times CF_{1,i}$$

where:

$C_{a,i}$	Activity concentration of radionuclide *I* in plume [kBq/m^3] from field measurement.
$CF_{1,i}$	Thyroid inhalation dose conversion factor for isotope *I* [(mSv/h)/(kBq/m^3)] from Table A1.
$\dot{H}_{thy}$	Dose rate to the thyroid from inhalation [mSv/h].

STEP 2

Calculate the ratios of the thyroid dose and the total effective dose rate to the external ambient dose rate as specified below:

$$R_2 = \frac{\dot{H}_{thy}}{\overline{\dot{H}^*}}$$

where:

R_2	Ratio of thyroid dose rate to ambient dose rate from inhalation of iodine (default assumed 200) [dimensionless].
$\overline{\dot{H}^*}$	Average ambient dose rate from external exposure in the plume where the air sample was taken from field measurements [mSv/h].
$\dot{H}_{thy}$	Dose rate to the thyroid from inhalation from Step 1 [mSv/h].
$\dot{E}_{inh}$	Effective dose rate from inhalation from Step 1 [mSv/h].

STEP 3

Recalculate OIL2 as specified below:

$$OIL2 = GIL_{thy} \times \frac{1}{R_2} \times \frac{1}{T_e}$$

where:

OIL2 Thyroid blocking operational intervention level as defined in Table A2 [mSv/h].

GIL_{thy} Generic intervention level for taking thyroid blocking [mSv].

T_e Exposure duration, assume 4 hours if unknown (typically the wind will shift every four hours) [h].

R_2 Ratio of thyroid dose rate to ambient dose rate from step 3 (default assumed 200) [dimensionless].

A3 Revision of Emergency Turn Back Guidance

This procedure is used to revise the emergency worker turn back guidance (EWG). The procedure should be performed only if there are reliable air samples, accident conditions are stable and a major release is on-going.

STEP 1

To recalculate the EWG value from field data, it is necessary to have the air concentrations of the major isotopic contributors to thyroid and effective dose from inhalation (include iodine and caesium) and the average ambient dose rate during the air sampling time ($\overline{\dot{H}^*}$) from field measurements. The thyroid dose and effective dose rate from inhalation of contaminated air are calculated from the summation of the contribution from each radionuclide.

$$\dot{E}_{inh} = \sum_i^n C_{a,i} \times CF_{2,i}$$

where:

$C_{a,i}$ Activity concentration of radionuclide *I* in plume [kBq/m^3] from field measurement.

$CF_{2,i}$ Effective inhalation dose conversion factor for isotope *I* [(mSv/h)/(kBq/m^3)] from Table A1.

$\dot{H}_{thy}$ Dose rate to the thyroid from inhalation [mSv/h].

$\dot{E}_{inh}$ Effective dose rate from inhalation [mSv/h].

STEP 2

Calculate the ratios of the thyroid dose and the total effective dose rate to the external ambient dose rate as specified below:

$$R_1 = \frac{\dot{E}_{inh}}{\overline{\dot{H}^*}} + 1$$

where:

R_1 Ratio of total effective dose rate to ambient dose rate (default assumed 10) [dimensionless].

$\overline{\dot{H}^*}$ Average ambient dose rate from external exposure in the plume where the air sample was taken from field measurements [mSv/h].

$\dot{E}_{inh}$ Effective dose rate from inhalation from Step 1 [mSv/h].

STEP 3

Recalculate the emergency worker turn back guidance as specified below.

Thyroid blocking taken:

$$EWG = E_T^{WG} \times \frac{5}{R_1}$$

where:

EWG Emergency worker turn back dose guidance [mSv].

E_T^{WG} Total effective dose guidance for emergency workers [mSv] - total effective dose which should not be exceeded when performing emergency tasks.

R_1 Ratio of total effective dose rate to ambient dose rate from Step 3 (default assumed 10) [dimensionless].

Thyroid blocking NOT taken:

Divide emergency worker turn back guidance calculated for thyroid blocking by 5.

Table A5: Inhalation Dose Rate Conversation Factors

Radionuclide	CF_1 Thyroid Inhalation Dose Conversion Factor $[(mSv/h)/(kBq/m^3)]$	CF_2 Effective Inhalation Dose Conversion Factor $[(mSv/h)/(kBq/m^3)]$
H-3 (a) (b)	NA	6.24×10^{-4}
Mn-54 (a)	NA	1.92×10^{-3}
Co-58 (a)	NA	2.52×10^{-3}
Co-60 (a)	NA	3.72×10^{-2}
Rb-87	NA	6.00×10^{-4}
Rb-88	NA	1.92×10^{-5}
Sr-89	NA	9.48×10^{-3}
Sr-90	NA	1.92×10^{-1}
Sr-91	NA	4.92×10^{-4}
Y-90	NA	1.80×10^{-3}
Y-91	NA	1.07×10^{-2}
Y-91m	NA	1.32×10^{-5}
Zr-95	NA	7.08×10^{-3}
Nb-95	NA	2.16×10^{-3}
Mo-99	NA	1.19×10^{-3}
Tc-99	NA	1.56×10^{-2}
Tc-99m	NA	2.28×10^{-5}
Ru-103	NA	3.60×10^{-3}
Rh-106	NA	1.32×10^{-4}
Sb-127	NA	2.28×10^{-3}
Sb-129	NA	3.00×10^{-4}
Te-127	NA	1.68×10^{-4}
Te-127m	NA	1.18×10^{-2}
Te-129	NA	4.68×10^{-5}
Te-129m	NA	9.48×10^{-3}
Te-131	3.16×10^{-3}	3.36×10^{-5}
Te-131m	4.33×10^{-2}	1.13×10^{-3}
Te-132	7.54×10^{-2}	2.40×10^{-3}
I-131	3.50×10^{-1}	8.88×10^{-3}
I-132	2.09×10^{-3}	1.32×10^{-4}
I-133	5.83×10^{-2}	1.80×10^{-3}
I-134	3.46×10^{-4}	6.60×10^{-5}

Radionuclide	CF_1 Thyroid Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m^3)]	CF_2 Effective Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m^3)]
I-135	1.02×10^{-2}	3.84×10^{-4}
Cs-134	NA	2.40×10^{-2}
Cs-136	NA	3.36×10^{-3}
Cs-137	NA	4.68×10^{-2}
Ba-140	NA	6.96×10^{-3}
La-140	NA	1.32×10^{-3}
Ce-141	NA	4.56×10^{-3}
Ce-144	NA	6.36×10^{-2}
Pr-144	NA	2.16×10^{-5}
Th-231	NA	3.96×10^{-4}
Np-239	NA	1.20×10^{-3}
Pu-238	NA	1.32×10^{2}
Pu-239	NA	1.44×10^{2}
Pu-240	NA	1.44×10^{2}
Pu-241	NA	2.76
Pu-242	NA	1.32×10^{2}
Am-241	NA	1.15×10^{2}

Source: IAEA 1997
NA Not applicable
(a) Important only for spent fuel pool
(b) Dose doubled to account for skin absorption

Note: For simplicity the dose conversion factors are provided in terms of mSv acquired in one hour, breathing an air concentration of 1 kBq/m^3.
A breathing rate of 1.2 m^3/h was assumed.

A4 Revision of Deposition Exposure Relocation OIL

This procedure is used to recalculate OIL4 (relocation based on ambient dose rates from deposition) for a known deposition isotope mixture. The isotopic mix of the deposition will change temporally (decay and ingrowth) and spatially. But for practical and human factors reasons only a single value for OIL4 should be used for the entire affected area. Therefore samples should be taken and analysed from a wide area to assure the value used is representative of the entire affected area. OIL4 should be re-evaluated every week for the first month to account for major changes in the composition of the deposition due to decay, and every month thereafter, until decay no longer has a major impact.

STEP 1

Using the field measurement data calculate the weighting ratio for the dose rate from ground deposition to the longer term dose from deposition using the formula below:

$$WR = \frac{\sum_{i}^{n}(C_{g,i} \times CF_{3,i})}{\sum_{i}^{n}(C_{g,i} \times CF_{4,i})}$$

where:

$C_{g,i}$ Isotope concentration of radionuclide *I* on the ground [kBq/m^2] from field measurements.
$CF_{3,i}$ Ambient dose rate conversion factor for deposition from Table A4.
$CF_{4,i}$ Long term dose conversion factor for deposition from Table A4.

STEP 2

Recalculate the relocation operational intervention level (OIL4) as specified below:

$$OIL4 = GIL_r \times WR \times \frac{1}{[SF \times OF + [1 - OF]]}$$

where:

OIL4 Relocation operational intervention level [mSv/h].
SF Shielding factor from measurements during occupancy (default 0.16) or from Table A5.
OF Occupancy fraction, or the fraction of time the shielding factor SF is applicable (e.g. the fraction of time spent indoors) default = 0.6
GIL_r Generic intervention level for relocation [mSv] from Table 1.
WR Weighting ratio for the dose rate from ground deposition to the longer term dose from deposition from Step 1.

OILs can be calculated for different periods. Initially the first month should be calculated to replace OIL4. Most principal isotopes contribute to the dose from external exposure from deposition for a reactor accident (NRC 1975).

Table A6: Shielding Factors for Surface Deposition

Structure or Location	Representative Shielding Factor (a,b)
One and two storey wood-frame house (without basement)	0.4
One and two storey block and brick house (without basement)	0.2
House basement, one or two walls fully exposed - one-storey, less than 1 m of basement, wall exposed - two storey, less than 1 m of basement, wall exposed	 0.1 0.05
Three or four storey structures (500 to 1000 m^2 per floor) - first and second floor - basement	 0.05 0.01
Multi-storey structures (> 1000 m^2 per floor) - upper floors - basement	 0.01 0.005

Source: (EGG 1975)

(a) The ratio of the interior to the exterior doses.
(b) Away from doors and windows.

Table A7 contains dose conversion factors (CF) for the first, second month and 50 year periods of exposure to ground contamination. Decay, ingrowth and weathering have been considered. The CF_4 includes dose from external exposure and inhalation dose from resuspension. An initial resuspension factor of $R_S = 1 \times 10^{-6}$/m was used because it is considered to be the upper bound (conservative) assuming weathered (old) deposition. However, much lower resuspension factors have been seen in real accidents. The ambient dose rate conversion factor (CF_3) is the exposure rate at 1 m above ground level from 1 kBq/m^2 deposition of isotope *I*, corrected for ground roughness (0.7). The table contains those radionuclides that are a major source of dose from deposition for a reactor accident.

Table A7: Dose and Dose Rate Conversion Factors for Exposure to Ground Contamination

Radionuclide	CF_3 (a) Ambient dose rate conversion factor for deposition [(mSv/h)/(kBq/m^2)]	CF_4 (b) Long term dose conversion factor for deposition [(mSv/kBq/m^2)]		
		1st Month	Subsequent Month	Lifetime (50 Year)
Mn-54	2.86×10^{-6}	1.39×10^{-3}	1.23×10^{-3}	1.40×10^{-2}
Co-58	3.35×10^{-6}	1.58×10^{-3}	9.39×10^{-4}	3.91×10^{-3}
Co-60	8.29×10^{-6}	4.15×10^{-3}	3.88×10^{-3}	1.65×10^{-1}
Rb-87	3.10×10^{-10}	NC	NC	NC
Rb-88	2.10×10^{-6}	NC	NC	NC
Sr-89	8.01×10^{-9}	1.05×10^{-5}	6.59×10^{-6}	2.83×10^{-5}
Sr-90	1.00×10^{-9}	1.69×10^{-4}	1.61×10^{-4}	2.11×10^{-2}
Sr-91	2.39×10^{-6}	3.38×10^{-5}	7.45×10^{-8}	3.40×10^{-5}
Y-90	1.88×10^{-8}	1.69×10^{-6}	6.71×10^{-10}	1.69×10^{-6}
Y-91	2.03×10^{-8}	1.66×10^{-5}	1.10×10^{-5}	4.94×10^{-5}
Y-91m	1.85×10^{-6}	1.59×10^{-6}	6.48×10^{-9}	1.61×10^{-6}
Zr-95 (c)	2.55×10^{-6}	1.38×10^{-3}	1.30×10^{-3}	6.83×10^{-3}
Nb-95 (c)	2.64×10^{-6}	9.98×10^{-4}	5.21×10^{-4}	2.09×10^{-3}
Mo-99+Tc-99m	9.53×10^{-7}	6.06×10^{-5}	3.08×10^{-8}	6.06×10^{-5}
Tc-99	2.75×10^{-10}	4.11×10^{-6}	3.88×10^{-6}	8.23×10^{-4}
Tc-99m	4.27×10^{-7}	2.65×10^{-6}	1.21×10^{-14}	2.65×10^{-6}
Ru-103 (c)	1.63×10^{-6}	6.40×10^{-4}	3.56×10^{-4}	1.45×10^{-3}
Ru-106+Rh-106	7.48×10^{-7}	4.24×10^{-4}	3.79×10^{-4}	4.80×10^{-3}
Rh-106	7.48×10^{-7}	NC	NC	NC
Sb-127	2.38×10^{-6}	2.26×10^{-4}	1.14×10^{-6}	2.28×10^{-4}
Sb-129 (c)	4.87×10^{-6}	2.30×10^{-5}	4.88×10^{-8}	2.31×10^{-5}
Te-127	1.83×10^{-8}	1.81×10^{-7}	1.81×10^{-7}	1.81×10^{-7}
Te-127m	3.99×10^{-8}	3.40×10^{-5}	2.67×10^{-5}	1.60×10^{-4}
Te-129	2.12×10^{-7}	2.53×10^{-7}	9.68×10^{-16}	2.53×10^{-7}
Te-129m	1.33×10^{-7}	1.05×10^{-4}	5.37×10^{-5}	2.15×10^{-4}
Te-131	1.45×10^{-6}	1.16×10^{-6}	3.83×10^{-8}	1.20×10^{-6}
Te-131m (c)	4.83×10^{-6}	1.97×10^{-4}	3.25×10^{-6}	2.00×10^{-6}
Te-132 (c)	8.04×10^{-7}	6.87×10^{-4}	1.13×10^{-6}	6.88×10^{-4}

Radionuclide	CF_3 (a) Ambient dose rate conversion factor for deposition [(mSv/h)/(kBq/m^2)]	CF_4 (b) Long term dose conversion factor for deposition [(mSv/kBq/m^2)]		
		1st Month	Subsequent Month	Lifetime (50 Year)
I-131 (c)	1.33×10^{-6}	2.48×10^{-4}	1.76×10^{-5}	2.67×10^{-4}
I-132 (c)	7.80×10^{-6}	1.85×10^{-5}	0.00	1.85×10^{-5}
I-133 (c)	2.11×10^{-6}	4.53×10^{-5}	0.00	4.53×10^{-5}
I-134	8.93×10^{-6}	8.06×10^{-6}	0.00	8.06×10^{-6}
I-135+Xe-135m (c)	5.40×10^{-6}	3.70×10^{-5}	0.00	3.70×10^{-5}
Cs-134 (c)	5.36×10^{-6}	2.66×10^{-3}	2.45×10^{-3}	5.12×10^{-3}
Cs-136 (c)	7.37×10^{-6}	1.87×10^{-3}	3.63×10^{-4}	2.32×10^{-3}
Cs-137+Ba-137m (c)	2.07×10^{-6}	9.94×10^{-4}	9.37×10^{-4}	1.25×10^{-1}
Cs-138	7.73×10^{-6}	NC	NC	NC
Ba-137m	2.07×10^{-6}	NC	NC	NC
Ba-140 (c)	6.35×10^{-7}	1.98×10^{-3}	4.36×10^{-3}	2.52×10^{-3}
La-140 (c)	7.62×10^{-6}	3.15×10^{-4}	1.19×10^{-9}	3.15×10^{-4}
Ce-141 (c)	2.60×10^{-7}	9.92×10^{-5}	4.94×10^{-5}	1.98×10^{-4}
Ce-144+Pr-144 (c)	2.01×10^{-7}	1.46×10^{-4}	1.29×10^{-4}	1.38×10^{-3}
Pr-144	1.33×10^{-7}	3.97×10^{-8}	0.00	3.97×10^{-8}
Pr-144m	4.59×10^{-8}	2.22×10^{-8}	0.00	2.22×10^{-8}
Th-231	6.53×10^{-8}	NC	NC	NC
Np-239 (c)	5.75×10^{-7}	3.35×10^{-5}	6.44×10^{-9}	3.39×10^{-5}
Pu-238 (c)	2.96×10^{-9}	3.88×10^{-2}	3.66×10^{-2}	6.55
Pu-239	1.29×10^{-9}	4.22×10^{-2}	3.99×10^{-2}	8.45
Pu-240	2.83×10^{-9}	4.22×10^{-2}	3.99×10^{-2}	8.44
Pu-241 (c)	6.81×10^{-12}	7.61×10^{-4}	7.20×10^{-4}	1.93×10^{-1}
Pu-242	2.35×10^{-9}	3.97×10^{-2}	3.75×10^{-2}	7.96
Am-241	9.70×10^{-8}	3.45×10^{-2}	3.26×10^{-2}	6.68

Source: IAEA 199
NC Not calculated
(a) Based on "Dose Conversion for Exposure to Contaminated Ground Surface" factors from U.S. EPA 1993, Table III.3. The effective dose was multiplied by 1.4 to estimate ambient dose rate. A ground roughness factor of 0.7 was used. The external dose from daughters expected to be in equilibrium is included where noted (e.g. Cs-137 + Ba-137m).
(b) Based on InterRAS [NRC 1994 and Appendix 2, IAEA 1997].

A5 Revision of I-131 Deposition Concentration OIL for Ingestion

This procedure is used to recalculate the ingestion operational intervention levels OIL6 (deposition concentrations of marker isotopes I-131). OIL6 is for either food that has been directly contaminated by the deposition or for milk from animals grazing on contaminated ground. Default values were calculated based on numerous assumptions about accidents and retention on food. (IAEA 1997) This procedure will use the actual relationship between the food or milk concentrations and the deposition concentration of I-131.

The mixture of the deposition could vary resulting in different relationships between the deposition concentrations of the marker isotope and food concentrations. In addition the OILs may vary depending on the food type and its preparation before consumption. Therefore the OILs for groups 1, 2, 4, and 5 (see Table 2) should be evaluated for different locations and food types (e.g. milk, fresh leafy vegetables, corn). Groups 3 and 6 will not be a concern for a Light Water Reactor accident.

While the OILs may vary with location, time, food type and preparation for practical and human factors reasons only a limited number of OILs should be used for the affected area. Single values should be developed for each major food type (e.g., cows milk, goats milk, leafy vegetables, fruit, other vegetables) that take into account its typical preparation before consumption. These values may require revision with time to reflect decay and weathering.

STEP 1

Using the measured food or milk and deposition isotope concentrations, taken at same location recalculate OIL6 for I-131 for groups 1 and 2 for the OIL for general consumption and for groups 4 and 5 for the OIL for milk. Recalculate the deposition concentration of I-131 for restriction of food (OIL6) using the formula below:

$$OIL6 = GAL_G \times \frac{C_{g,I\text{-}131}}{\sum_i^n C_{G,i}}$$

where:

OIL6 Operational intervention level for deposition concentration [kBq/m^2] of I-131 used to identify where locally produced food (OIL6F) or milk (OIL6M) consumption should be restricted. For goat milk use 1/10 of OIL6M.

GAL_G Generic Action Level for group G in Table 2.

$C_{g,I\text{-}131}$ Deposition concentration of I-131 [kBq/m^2] from field measurements.

$C_{G,i}$ Concentration of each radionuclide *I* in group G in the food sample (see Table 2) [kBq/kg] from field measurements. Assure that:

a) the concentration in the milk represents the maximum concentration possible for a cow grazing at that location; and
b) the food concentrations represent those in the food at time of consumption.

Procedure C9 can be used to adjust milk and food concentrations.

n number of measured radionuclides in the isotope group G.

A6 Revision of Cs-137 Deposition Concentration Oil for Ingestion

OIL7 is for either food that has been directly contaminated by the deposition or for milk from animals grazing on contaminated ground. Default values were calculated based on numerous assumptions about accidents and retention on food (IAEA 1997). This procedure will use the actual relationship between the food or milk concentrations and the deposition concentration of Cs-137.

The mixture of the deposition could vary resulting in different relationships between the deposition concentrations of the marker isotope and food concentrations. In addition the OILs may vary depending on the food type and its preparation before consumption. Therefore the OILs for groups 1, 2, 4, and 5 (see Table 2) should be evaluated for different locations and food types (e.g. milk, fresh leafy vegetables.

While the OILs may vary with location, time, food type and preparation for practical and human factors reasons only a limited number of OILs should be used for the affected area. Single values should be developed for each major food type (e.g., cows milk, goats milk, leafy vegetables, fruit, other vegetables) that take into account its typical preparation before consumption. These values may require revision with time to reflect decay and weathering.

STEP 1

Using the measured food or milk and deposition isotope concentrations, taken at same location recalculate OIL8 for C3-137 for groups 1 and 2 for the OIL for general consumption and for groups 4 and 5 for the OIL for milk. Recalculate the deposition concentration of Cs-137 for restriction of food (OIL7) using the formula below:

$$OIL7 = GAL_G \times \frac{C_{g,Cs\text{-}137}}{\sum_i^n C_{G,i}}$$

where:

- *OIL7* Operational intervention level for deposition concentration [kBq/m²] of Cs-137 to identify where locally produced food (OIL7F) or milk (OIL7M) consumption should be restricted. For goat milk use 1/10 of OIL7M.
- GAL_G Generic Action Level for group G in Table 2.
- $C_{g,Cs\text{-}137}$ Deposition concentration of Cs-137 [kBq/m²] from field measurements.
- $C_{G,i}$ Concentration of each radionuclide *I* in group G (see Table 2) [kBq/kg] in the food sample from field measurements. Assure that:
  - a) the concentration in the milk represents the maximum concentration possible for a cow grazing at that location; and
  - b) the food concentrations represent those in the food at time of consumption.
- *n* number of measured radionuclides in the isotope group G.

STEP 2

Prepare a set of recommended OIL for the major food types.

A7 Evaluation of Food Restrictions and Revision of I-131 Food OILs

This procedure is used to determine if concentration levels found in food, drinking water, or milk exceed the ingestion Generic Action Levels (GALs) and to recalculate OIL8 (food restriction based on I-131 as the marker isotope). Once the detailed isotopic concentration of foodstuff is known, they can be compared with the GALs directly. Once a representative isotopic composition has been obtained by food type, it is possible to calculate operational intervention levels based on a single marker isotope (Cs or I) that take into account the presence of the other isotopes in a GAL group (see Table 2). They are only valid for surface contamination, i.e. they do not account for root uptake by various plants.

STEP 1 - *Direct comparison to GALs*

Determine if the contamination in food, water or milk may exceed the GALs.

$$\sum_{i}^{n} C_{G,i} > GAL_G$$

where:

$C_{G,i}$ Isotope concentration in sample of each isotope *I* from group G from field sample measurements. Ensure that the food concentrations represent those in the food at time of consumption. Procedure C9 can be used to adjust food concentrations.

GAL_G Generic Action Level for group G from Table 2 [kBq/kg].

n number of measured radionuclides in food, milk or water in the isotope group G.

If the sum for concerned food is greater than corresponding GAL it indicates that the levels for restriction of food have been exceeded.

STEP 2

Using field sample measurement data recalculate the operational intervention levels for marker isotope concentrations in food, water or milk samples. Use groups 1 and 2 for the OIL for general consumption and groups 4 and 5 for the OIL for milk.

Recalculate OIL8 for I-131 using the formula below:

$$OIL8 = GAL_G \times \frac{C_{f,I\text{-}131}}{\sum_{i}^{n} C_{G,i}}$$

where:

$OIL8$ Operational intervention level for activity concentration in food (OIL8F) milk or water (OIL8M) for I-131 [kBq/kg].

$C_{G,i}$ Isotope concentration in the representative food sample of each isotope *I* in group G from field sample measurement data [kBq/kg].

$C_{f,I\text{-}131}$ Isotope concentration of I-131 in representative food sample from field sample measurement data [kBq/kg].

GAL_G Generic Action Levels for group G from Table 2 [kBq/kg].

A8 Evaluation of Food Restrictions and Revision of Cs-137 Food OILS

This procedure is used to determine if concentration levels found in food, drinking water, or milk exceed the ingestion Generic Action Levels (GALs) and to recalculate OIL9 (food restriction based on Cs-137 as the marker isotope). Once the detailed isotopic concentration of foodstuff is known, they can be compared with the GALs directly. Once a representative isotopic composition has been obtained by food type, it is possible to calculate operational intervention levels based on a single marker isotope (Cs or I) that take into account the presence of the other isotopes in a GAL group (see Table 2). They are only valid for surface contamination, i.e. they do not account for root uptake by various plants.

STEP 1 - *Direct comparison to GALs*

Determine if the contamination in food, water or milk may exceed the GALs.

$$\sum_{i}^{n} C_{G,i} > GAL_G$$

where:

$C_{G,i}$ Isotope concentration in sample of each isotope *I* from group G from field sample measurements. Ensure that the food concentrations represent those in the food at time of consumption.

GAL_G Generic Action Level for group G from Table 2 [kBq/kg].

n number of measured radionuclides in food, milk or water in the isotope Group G.

If the sum for concerned food is greater than the corresponding GAL it indicates that the levels for restriction of food have been exceeded.

STEP 2

Using G from field sample measurements recalculate the operational intervention levels for marker isotope concentrations in food, water or milk samples. Use groups 1 and 2 for the OIL for general consumption and groups 4 and 5 for the OIL for milk.

Recalculate OIL9 for Cs-137 using the formula below:

$$OIL9 = GAL_G \times \frac{C_{f,Cs\text{-}137}}{\sum_{i}^{n} C_{G,i}}$$

where:

$OIL9$ Operational intervention level for activity concentration in food (OIL9F) and milk or water (OIL9M) for Cs-137 [kBq/kg].

$C_{G,i}$ Isotope concentration in representative food sample of isotope *I* for each isotope in group G from G from field sample measurements [kBq/kg].

$C_{f,Cs\text{-}137}$ Isotope concentration of Cs-137 in representative food sample from G from field sample measurements [kBq/kg].

GAL_G Generic Action Levels for group G from Table 2 [kBq/kg].

A9 Calculation of Isotope Concentrations in Food

This procedure is used to calculate the contamination levels in food after processing or milk produced by cows grazing on contaminated ground. Concentrations of radionuclides in food and milk can be altered by several natural and man-made mechanisms. The concentration of Cs, I and Sr will increase in milk for approximately the first 72 hours following consumption of contaminated feed by cows and goats. Reduction mechanisms include:

- dilution with uncontaminated food stuff;
- washing;
- filtering; and
- radioactive decay.

Step 1

Determine maximum concentration of isotope in cows milk using the equation below:

$$C_i^{max} = C_i^{samp} \times cf_i(T_{rs})$$

where:

C_i^{max} Projected maximum cow milk isotope concentration after consumption of contaminated feed.

C_i^{samp} Measured cow milk isotope concentration after consumption of contaminated feed.

cf_i (T_{rs}) Milk concentration conversion factor for isotope I taken from Table A8.

T_{rs} Time the sample was taken after the start of intake of contaminated diet. This can be estimated by the time from the beginning of the release to the time the sample was collected.

Table A8: Milk Concentration Conversion Factors

Milk Concentration Conversion Factors CF_i			
T_{rs}	I-131	Cs-137	Sr-90
12	3.0	4.0	5.3
24	1.7	2.0	2.5
36	1.1	1.6	2.1
48	1.0	1.3	1.6
60	1.0	1.2	1.4
72	1.0	1.1	1.3
84	1.0	1.1	1.2
96	1.0	1.0	1.1
108	1.0	1.0	1.0

Step 2

If decay or other removal processes are used to decrease the concentration in the milk, food or drinking water calculate the adjusted concentrations. Use the following:

$$C_{i(before)} \times \prod_{j}^{n} RF_{i,j} \times \frac{W(before)}{W(after)} = C_{i(after)}$$

where:

C Concentration of isotope *I* in food, before and after decay or processing.

RF Reduction factor is the fraction of the isotope remaining after decay or some removal process before food is released for consumption. The reduction factor for processing, washing, filtering or other treatment should be based on tests conducted before and after the process. The Table A8 provides estimates of the effectiveness of various processes in removing contamination. Using the parameter of reduction factor, it is necessary to take into account change in volume between initial product and prepared foodstuff. This is most important for processing of milk. For example, RF=0.61 for Sr for goat cheese means that 39% of radio strontium is removing from the product during the process of cheese preparation. But with consideration that effective quantity of cheese is 12% from initial volume of milk, radio strontium concentration in cheese will be 5 time higher than its initial concentration in milk (0.61/0.12=5). Accordingly, for estimation of total reduction effect during process of preparation it is necessary to divide parameters of RF to appropriate numbers of effective quantities. Effective quantity is determined as weight of a prepared product divided to weight of an initial product.

$\prod_{j}^{n} RF_{i,j}$ Multiply by all reduction factors that apply (RF_1 x RF_2 x ... x RF_n).

W (before) Weight of the initial product.

W (after) Weight of the prepared foodstuff.

The reduction factor for decay is:

$$RF = 0.5^{(T_d \,/\, T_{1/2})}$$

where:

$T_{1/2}$ Half life.

T_d Time food is held up before consumption.

Note: ensure that T_d and $T_{1/2}$ have the same units.

Table A9 Reduction Factors for Processing or Filtering for Food

Element	Food	Preparation	RF
Iodine	Spinach	washing	0.8
		washing and boiling	0.7
		rinsing	0.4
	Leaf lettuce	washing	0.5
		rinsing (15 minutes)*	0.2
		rinsing (20 hours)*	0.7
	Cabbage	washing	0.5
		outer leaves removing	0.4
	Cauliflower	peeling	0.03
		rinsing (15 minutes)*	0.3
		rinsing (20 hours)*	0.4
		boiling (15 minutes)*	0.1
	Green beans	rinsing (15 minutes)*	0.3
		rinsing (20 hours)*	0.7
		boiling (15 minutes)*	0.2
	Tomatoes	washing	0.5
		boiling	0.2
	Onions	ends and outer parts removing	0.2
		washing	0.2
	Celery	rinsing (15 minutes)*	0.5
		rinsing (20 hours)*	0.7
		boiling (15 minutes)*	0.2
	Peppers	rinsing (15 minutes)*	0.4
		boiling (15 minutes)*	0.3
	Milk	cream	0.19
		butter	0.035
		boiled butter	0.2
		milk powder	1.0
		goat cheese	0.14
	Meat	boiling of meat	0.6
		boiling of bones	0.98

Element	Food	Preparation	RF
	Fish	boiling	0.9
		frying	0.8
Caesium	Spinach	washing	0.9
		washing and boiling	0.9
	Leaf lettuce	washing	1.0
	Cabbage	outer leaves removing	0.9
		washing	0.09
		washing and boiling	0.7
	Cauliflower	peeling	0.03
	Green beans	boiling	0.3
		salting	0.4
	Onions	ends and outer parts removing	0.2
		washing	0.3
	Potatoes	peeling	0.8
		peeling and boiling	0.6
	Carrots	peeling	0.5
	Beets	peeling	0.7
		usual preparation after peeling	0.7
	Cereals	milling in white flour	0.6
		milling in bran	0.7
	Dough flour	baking	0.9
	Rye	milling and baking	0.7
	Milk	cream	0.05
		butter	0.01
		boiled butter	0.00
		milk powder	1.00
		goat cheese	0.15
		yoghurt	0.3
		whey	0.9
	Meat	boiling meat	0.7
		boiling bones	0.3
		frying	0.8

Element	Food	Preparation	RF
		wet salting	0.7
		dry salting	0.8
		pickling	0.6
	Fish	boiling	0.9
		frying	0.9
	Mushrooms	cleaning and washing	0.8
		boiling with pouring out of the first water	0.6
		drying	0.5
		frying	0.3
		pickling	0.3
	Berries	washing	0.9
		cooking of jam	0.5
Strontium	Spinach	washing	0.2
		washing and boiling	0.7
	Cabbage	washing	0.07
		washing and boiling	0.3
	Green beans	washing	0.3
		salting	0.4
	Tomatoes	washing and slicing	0.7
	Onions	peeling, washing and boiling	0.6
	Potatoes	peeling	0.9
		peeling and boiling	0.8
		frying	0.6
	Carrots	scraping, washing and boiling	0.8
	Carrots	peeling	0.7
	Beets	peeling	0.8
	Cereals	milling in white flour	0.6
		milling in bran	0.9
	Rye	milling and baking	0.7
	Rice	polished	0.1
	Milk	cream	0.07
		butter	0.006

Element	Food	Preparation	RF
		boiled butter	0.002
		milk powder	1.0
		goat cheese	0.61
		whey	0.8
	Meat	boiling meat	0.5
		boiling bones	0.999
		frying	0.8
	Fish	boiling	0.9

* *Time between contamination of the surface and start of removal process.*

> ***Note:*** *Processing or filtering such as water filtration, washing produce or other preparation or culinary practice remove contamination. The reduction factor is based on measurements of contamination conducted before and after the process. The table below provides estimates of the effectiveness of various processes in removing contamination (IAEA 1994a).*

ANNEX A REFERENCES

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Glossary

A

accident

Any unintended event, including operating error, equipment failure or other mishap, the consequences or potential consequences of which are not negligible from the point of view of *protection and safety*.

action level

see *level*

activity

The rate at which atomic disintegrations occur in a radioactive material. Mathematically:

$$A(t) = \frac{dN}{dt}$$

where dN is the expectation value of the number of spontaneous nuclear transformations from the given energy state in the time interval dt. The SI unit is the reciprocal second, given the special name Becquerel (Bq).[1] 1Bq = 1 disintegration/s

specific activity: The *activity* of a radionuclide per unit mass of a material. This term is preferred for cases where the radionuclide is intrinsically present in the material (e.g. ^{14}C in organic materials, ^{235}U in natural uranium), even if the abundance of the radionuclide is artificially changed. If the radionuclide is present only as *contamination* or as a result of artificial activation, then the term *activity concentration* is preferred.

activity concentration

The *activity* of a radionuclide per unit mass (or per unit volume) of a material or per unit surface area. See also *specific activity*.

acute dose

Dose received over a short period of time (e.g. days). See also *dose*.

ambient dose rate

See *dose rate*

assessment

The process, and the result, of analysing systematically the hazards associated with *sources* and practices, and associated *protection and safety* measures, aimed at quantifying performance measures for comparison with criteria.

atomic mass number (A)

The sum of the number of protons and neutrons in the atom.

avertable dose

See *dose*.

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1 The curie (Ci), equal to 3.7×10^{10} becquerels is sometimes used as a unit of *activity*.

averted dose

See *dose*.

B

background (radiation)

Ionizing radiation normally present in the region of interest and coming from sources other than that of primary concern.

becquerel

The specific name for the unit of *activity* of a *radionuclide*. See also *activity*.

C

calibration

A measurement of, or adjustment to, an instrument, component or system to ensure its accuracy or response is acceptable.

cloud shine

Gamma radiation from radioactive materials in an airbourne plume.

concentration

See *activity concentration*.

contamination

The presence of radioactive substances or materials on surfaces, or within solids, liquids or gases (including the human body), where they are not intended.

fixed contamination: *Contamination* other than *non-fixed contamination*.

non-fixed contamination: *Contamination* that can easily be removed from a surface.

countermeasure

An *intervention* aimed at alleviating the radiological consequences of an *accident*. These may be *protective actions* or *remedial actions*, and these more specific terms should be used where possible.

D

decontamination

The complete or partial removal of *contamination* by a physical or chemical process.

deposition

The *contamination* found on or within a few cm of the surface of the ground or on the surface of other material.

deterministic effect

A health effect that is certain to occur - with a severity that increases with increasing *dose* - in an individual exposed to a radiation *dose* greater than some threshold *dose*. The level of the threshold *dose* is characteristic of the particular health effect but may also depend, to a limited extent, on the exposed individual. Examples of *deterministic effects* include erythema and radiation sickness. See also *stochastic effect*.

dose

A measure of the energy transferred from radiation to a target. Commonly used without qualification when the context makes the qualifier obvious, or as a general term where different qualifiers could equally validly be used. See also *absorbed dose*, *collective dose*, *effective dose*, *equivalent dose* and *organ dose*.

absorbed dose: The energy transferred from radiation to unit mass of the exposed matter, unit J/kg, given the special name gray (Gy)[2]. Mathematically defined as:

$$D = \frac{d\bar{\varepsilon}}{dm}$$

i.e. the mean energy imparted to the matter in a volume element divided by the mass of the volume element. This term is therefore defined at a point; for the average in a tissue or organ, see *organ dose*.

annual dose: The *dose* received from *external exposure* in a year plus the *committed dose* from intakes of radionuclides in that year. Therefore this is not, in general, the *dose* actually received in that year.

avertable dose: A prospective estimate of the *averted dose* expected to result if a specified *countermeasure* or set of *countermeasures* were to be applied.

averted dose: A retrospective estimate of the *dose* prevented by the *countermeasure* or set of *countermeasures* applied, i.e. the difference between the *projected dose* if the *countermeasure(s)* had not been applied and the actual *projected dose*.

collective dose: The total *dose* to a defined population. Unless otherwise specified, the time over which the *dose* is integrated is infinite; if a finite upper limit is applied to the time integration, the *collective dose* is described as ‘truncated’ at that time. The relevant *dose* is normally *effective dose*, and the unit is the man sievert (man·Sv).

committed dose: The *dose* resulting from an intake of radioactive material, integrated over the 50 years after intake, (or integrated to age 70 years for intake as an infant or child). The relevant *dose* may be *absorbed dose*, *effective dose*, *equivalent dose* or *organ dose*, with units Gy or Sv as appropriate.

effective dose: A measure of *dose* designed to reflect the amount of *radiation detriment* likely to result from the *dose*, calculated as the weighted sum (using *tissue weighting factors* w_T) of the *equivalent doses* H_T in the different tissues of the body, i.e.:

$$E = \sum_T w_T H_T$$

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2 The rad, equal to 0.01 gray, is sometimes used as a unit of *absorbed dose*.

Values of *effective dose* from any type(s) of radiation and mode(s) of *exposure* can therefore be compared directly. Unit J/kg, given the special name sievert (Sv)[3].

equivalent dose: A measure of the *dose* to a tissue or organ designed to reflect the amount of harm caused, calculated as the product of the average *absorbed dose* in the tissue or organ and the appropriate *radiation weighting factor*. Values of *equivalent dose* to a specified tissue from any type(s) of radiation can therefore be compared directly. Symbol H_T, unit J/kg, given the special name sievert (Sv).

organ dose: The average *absorbed dose* in a tissue or organ, i.e. the total energy imparted in a tissue or organ divided by the mass of the tissue or organ.

projected dose: The *dose* that would be expected to be received if a specified *countermeasure* or set of *countermeasures* — especially no *countermeasures* — were to be taken.

dose coefficient

The *committed effective dose* from intake, by a specified means (usually ingestion or inhalation), of unit *activity* of a specified radionuclide in a specified chemical form. Values are specified in the BSS 115. Formerly termed dose per unit intake.

dose equivalent

A measure of the *dose* to a tissue or organ designed to reflect the amount of harm caused, calculated as the product of the average *absorbed dose* in the tissue or organ and the appropriate *quality factor*. Superseded by *equivalent dose* (see *dose*) as a primary quantity recommended by ICRP, and in the calculation of *effective dose*. However, the definitions of a number of operational *dose* quantities still refer to this term.

ambient dose equivalent: A directly measurable proxy for *effective dose* for use in *environmental monitoring* of *external exposure*. Defined by ICRU as 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, symbol $H^*(d)$. The recommended value of *d* for *strongly penetrating radiation* is 10 mm.

dose rate

A measure of the rate at which energy is transferred from radiation to a target. Commonly used without qualification when the context makes the qualifier obvious, or as a general term where different qualifiers could equally validly be used, e.g. *absorbed dose rate*, *equivalent dose rate*

E

effective dose

See *dose*.

effective dose equivalent

[3] The rem, equal to 0.01 sievert, is sometimes used as a unit of *equivalent dose* and *effective dose*.

See *dose equivalent*.

emergency action level
See *level*.

emergency plan
A set of procedures to be implemented in the event of an *accident*.

emergency planning zone
The *off-site* area around an *authorized facility* for which planned *protective actions* are described in the *emergency plan*.

emergency worker
Person performing emergency services.

emergency worker guidance
Total *dose* personnel should make every attempt not to exceed while performing emergency services.

environmental monitoring
See *monitoring*.

evacuation
The removal of persons from locations where *projected doses* are high, as an immediate *protective action* in an emergency *intervention* situation.

exposure
The act or condition of being subject to irradiation

acute exposure: A descriptive term for *exposure* occurring within a defined (short) period of time.
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.

external exposure: *Exposure* from a *source* outside the body.

internal exposure: *Exposure* from a *source* inside the body.

occupational exposure: All *exposures* of *workers* incurred in the course of their work, with the exception of *excluded exposures* and *exposures* from *exempt practices* or exempt *sources*.

potential exposure: *Exposure* that is not certain to occur but that may result from an event or sequence of events of a *probabilistic* nature, including *accidents* and events influencing the integrity of a *waste repository*.

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.

exposure pathway
The routes by which radioactive material can reach or irradiate humans.

external exposure
See *exposure*.

F

G

generic intervention level (GIL)
The generic level of *avertable dose* at which specific *protective action* or remedial action is taken in an *emergency exposure* situation or a *chronic exposure* situation. Values are specified in the BSS 115.

generic action level (GAL)
The level of *activity concentration* above which remedial actions or protective actions should be carried out in chronic exposure or emergency exposure situations.

gray
The name for the unit of absorbed *dose*; see also *dose*.

ground shine
Gamma radiation from radioactive materials deposited on the ground.

H

half-life
The time taken for the *activity* of a radionuclide to halve as a result of radioactive decay. Also used with qualifiers to indicate the time taken for the quantity of a specified material (e.g. a radionuclide) in a specified place to halve as a result of any specified process or processes that follow similar exponential patterns to radioactive decay.

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.

effective half-life: The time taken for the *activity* of a radionuclide in a specified place to halve as a result of all relevant processes.

hot spot
Localized areas where *dose rates* or *contamination* as a result of *deposition* are much higher than in the surroundings.

I

immersion
To be surrounded or engulfed by the radioactive cloud.

individual monitoring
See *monitoring*.

inhalation dose

Committed dose resulting from inhalation of radioactive materials and subsequent deposition of these *radionuclides* in body tissues.

internal exposure

See *exposure*.

intervention

Any action intended to reduce or avert *exposure* or the likelihood of *exposure* to *sources* which are not part of an authorized practice (or an exempt practice), or which are out of control as a consequence of an *accident*.

intervention level

See *level*.

isotope

Nuclide of a particular element that contain the same number of protons but different number of neutrons.

marker isotope: An isotope contained in deposition or sample that is easily identified in the field or laboratory. It is used to determine areas of concern before performing a comprehensive isotopic analysis.

L

level

action level: In general, the value of a specified measurable quantity above which a specified action will be taken. Most commonly used to mean a 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.

guidance level: A level of a specified quantity above which appropriate actions should be considered. In some circumstances, actions may need to be considered when the specified quantity is substantially below the guidance level.

intervention level: The level of *avertable dose* at or above which a specific *protective action* or *remedial action* is taken in an *emergency exposure* or *chronic exposure* situation.

operational intervention level: A calculated value (e.g. *ambient dose rate* or *activity concentration*) measured by instruments or determined by laboratory analysis that correspond to a *GIL* or *GAL*.

limit

The value of a quantity that must not be exceeded.

dose limit: A *limit* on the total *annual effective dose* to an individual (or the average *annual effective dose* over a specified number of years) or the *annual equivalent dose* to a tissue or organ from specified *sources*. The BSS 115 specify dose limits for *workers* and *members of the public*.

M

member of the public

In a general sense, any individual in the population except when subject to *occupational exposure* or *medical exposure*. For the purpose of verifying compliance with the annual *dose limit* for *public exposure*, the representative individual in the relevant critical group.

monitoring

The measurement of radiological or other parameters for reasons related to the *assessment* or control of *exposure*, and the interpretation of such measurements. Also used in nuclear safety for the periodic or continuous determination of the status of a system.

environmental monitoring: *Monitoring* in which the parameters measured relate to characterizing an environment allowing the possible *exposure* in that environment to be estimated.

individual monitoring: *Monitoring* in which the parameters measured relate to the *exposure* that a specific individual (most commonly a *worker*) is receiving.

N

natural exposure

See *exposure*.

non-fixed contamination

See *contamination*.

nuclide

Any *isotope* of an atom, a nuclear species.

O

occupational exposure

See *exposure*.

operational intervention level (OIL)

See *level*.

P

plume (atmospheric)

The airbourne "cloud" of material released to the environment, which may contain radioactive materials and may or may not be invisible.

projected dose

See *dose*.

protection

radiation protection or ***radiological protection:*** Used in two slightly different ways. For the more general usage — protection against radiological hazards — see *protection and safety*. The term *radiation protection* is also often used in the context of operating *nuclear installations* to refer specifically to those measures related to the control of *occupational exposure*, as distinct from prevention and mitigation of *accidents*, the control of discharges or waste management.

protection and safety

The protection of people against *exposure* to ionizing radiation or radioactive materials and the safety of radiation *sources*, including the means for achieving this, and the means for preventing *accidents* and for mitigating the consequences of *accidents* should they occur.

protective action

An *intervention* intended to avoid or reduce *doses* to *members of the public* in *chronic exposure* or *emergency exposure* situations. See also *remedial action*. Also used in nuclear safety, for a protection system action calling for the operation of a particular safety actuation device.

Q

quality assurance

All those planned and systematic actions necessary to provide adequate confidence that an item or service will satisfy given requirements for quality.

quality factor

A number by which the *absorbed dose* in a tissue or organ was multiplied to reflect the *relative biological effectiveness* of the radiation, the result being the *dose equivalent*. Superseded by *radiation weighting factor* in the definition of *equivalent dose* by ICRP, but still defined, as a function of *linear energy transfer*, for use in calculating the *dose equivalent* quantities used in *monitoring*.

R

radiation weighting factor

A number by which the *absorbed dose* in a tissue or organ is multiplied to reflect the *relative biological effectiveness* of the radiation in inducing *stochastic effects* at low *doses*, the result being the *equivalent dose*. Values are specified by ICRP as a function of unrestricted *linear energy transfer*. See also *quality factor*.

radioactive half-life

See *half-life*.

radioactive decay

Transformation of unstable isotopes into a more stable form, accompanied by the emission of particles and/or gamma rays.

radioiodine

One or more of the radioactive isotopes of iodine.

radionuclide

A nucleus (of an atom) that possesses properties of spontaneous disintegration (radioactivity). Nuclei are distinguished by both their mass and atomic number.

relocation

The removal of *members of the public* from their homes for an extended period of time, as a *protective action* in a *chronic exposure* situation.

remedial action

Action taken to reduce *exposures* that might otherwise be received, in an *intervention* situation involving *chronic exposure*. Actions applied to people in any type of situation would normally be considered *protective actions* rather than *remedial actions*. See also *protective action*.

S

sealed source

See *source*.

sheltering

A *protective action* whereby *members of the public* are advised to stay indoors with windows and doors closed, intended to reduce their *exposure* in an *emergency exposure* situation.

sievert

The name for the unit of *equivalent dose*. See also *dose*.

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.

natural source: A naturally occurring *source* of radiation, such as the sun and stars (*sources* of cosmic radiation) and rocks and soil (terrestrial *sources* of radiation).

sealed source: Radioactive material that is (a) permanently sealed in a capsule, or (b) closely bounded and in a solid form. The term *special form radioactive material*, used in the context of *transport* of radioactive materials, has a very similar meaning.

unsealed source: Any *source* that does not meet the definition of a *sealed source*.

source term

An expression used to denote information about the actual or potential release of radioactive material from a given *source*, most commonly in the case of an *accident*. This may include information about the radionuclides present, and the composition, quantity, rate and mode of release of the material.

stable iodine

Iodine which is comprised of only non-radioactive isotopes of iodine. See also *thyroid blocking agent*.

stochastic effect

A 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 cancer and leukemia. See also *deterministic effect*.

survey

radiological survey: An evaluation of the radiological conditions and potential hazards associated with the production, use, transfer, release, disposal, or presence of radioactive material or other *sources* of radiation.

T

thyroid blocking agent

A substance which prevents or reduces the uptake of radioactive iodine by the thyroid. Usually stable potassium iodide (KI) is taken orally for this purpose.

tissue weighting factor

Numbers by which the *equivalent dose* to tissues or organs are multiplied to account for their different sensitivities to the induction of *stochastic effects* of radiation. Values for use in the calculation of *effective dose* are specified by ICRP 60[8].

turn back guidance

An integrated dose reading on a self reading dosimeter indicating that an emergency worker dose guidance has been exceeded and that the emergency worker should leave the areas where further significant dose is possible.

W

waste disposal

The emplacement of *radioactive waste* in an appropriate facility with no intention of retrieving it.